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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

USDA Forest Service
General Technical Report INT-34
May 1977

FOREST HABITAT TYPES OF MONTANA

Robert D. Pfister, Bernard L. Kovalchik, Stephen F. Arno,

and Richard C. Presby

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INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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David Ondov handled most of the computer programing in addition to serving as a field and lab technician. Other University of Montana students, Gerald Moore, Jeffrey Hart, and Marla Kapperud, served as valuable research assistants.

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CONTENTS

Page

INTRODUCTION 1

- Objectives and Scope 1

METHODS 3

- Plot Sampling 3
- Office Procedures 5
- Taxonomic Considerations 8
- Synecological Perspective and Terminology 9

THE PHYSICAL SETTING 11

- Topography and Geology 11
- Soils 12
- Climate and Microclimate 13

SUCCESSIONAL STATUS OF MONTANA FORESTS 14

- Fire History 14
- Grazing History 15
- Logging History 15

THE HABITAT TYPE CLASSIFICATION 16

- *Pinus flexilis* Series 18
- *Pinus ponderosa* Series 27
- *Pseudotsuga menziesii* Series 35
- *Picea* Series 56
- *Abies grandis* Series 66
- *Thuja plicata* and *Tsuga heterophylla* Series 70
- *Abies lasiocarpa* Series 76
- *Pinus contorta* Series 115
- Other Vegetation Types 121

CHARACTERIZATION AND DISTRIBUTION OF HABITAT TYPES 124

- Climate 124
- Soils 124
- Vegetation 126
- Geographic Distributions of Habitat Types 131
- Relationship to Other Habitat Type Classifications 136

Page

USE OF THE CLASSIFICATION 139

Validation 139
Use of Habitat Types 139
Mapping. 140
Grouping 141

PUBLICATIONS CITED. 142

APPENDIXES 149

A. Number of Sample Plots by Habitat Type, Phase, and National Forest in Montana 150
B. Distribution of Tree Species in Montana Habitat Types Showing Their Dynamic Status as Interpreted From Sample Stand Data 152
C-1. Constancy and Average Canopy Coverage Percent of Important Plants in Montana Forest Habitat Types and Phases. 153
C-2. Presence List: Numbers of Sample Stands Where Each Species Occurred, by Habitat Type and Phase. (Located in Pocket Inside Back Cover.) . . 160
D-1. General Soil Characteristics. 161
D-2. Climatic Parameters for Stations Within Selected Habitat Types in or Near Montana 166
E-1. Mean Basal Areas and 50-Year Site Indexes for Montana Stands, by Species and Habitat Type 167
E-2. Mean Maximum Heights (in Feet) for Montana Stands by Tree Species and Habitat Type 168
E-3. Estimated Yield Capabilities of West-Side Montana Habitat Types Based on Site Index Data and Stockability Factors 169
E-4. Estimated Yield Capabilities of East-Side Montana Habitat Types Based on Site Index Data and Stockability Factors 170
F. Montana Habitat Type Field Form 171
G. Glossary 172

FIGURES: Page

1. Geographic subdivisions and National Forests of Montana 2
2. Generalized successional stages of each forest series, showing the types of stands sampled as the basis for our habitat type classification 3
3. Distribution of mountain ranges in Montana 12
4. Generalized climax zonation of the coniferous forest series in Montana . . 16
5. Generalized distribution of forest trees and climax series in southwestern and south-central Montana. 17
6. Generalized distribution of forest trees and climax series in an area of northwestern Montana 18
7. Key to climax series, habitat types, and phases 19
8. *Pinus flexilis*/*Festuca idahoensis* h.t. (*F. scabrella* phase) 23
9. *Pinus flexilis*/*Juniperus communis* h.t. 24
10. *Pinus ponderosa*/*Agropyron spicatum* h.t. 28
11. *Pinus ponderosa*/*Festuca idahoensis* h.t. (*F. idahoensis* phase) 28
12. *Pinus ponderosa*/*Prunus virginiana* h.t. (*P. virginiana* phase) 28
13. *Pseudotsuga menziesii*/*Agropyron spicatum* h.t. 36
14. *Pseudotsuga menziesii*/*Vaccinium globulare* h.t. (*Arctostaphylos uva-ursi* phase) 36
15. *Pseudotsuga menziesii*/*Vaccinium caespitosum* h.t. 40
16. *Pseudotsuga menziesii*/*Physocarpus malvaceus* h.t. (*Physocarpus* phase) 42
17. *Pseudotsuga menziesii*/*Physocarpus malvaceus* h.t. (*Calamagrostis* phase) 42
18. *Pseudotsuga menziesii*/*Symphoricarpos albus* h.t. (*Calamagrostis* phase) 46
19. Generalized distribution of key indicator species within phases of the *Pseudotsuga*/*Calamagrostis* h.t. 48
20. *Pseudotsuga menziesii*/*Calamagrostis rubescens* h.t. (*Pinus ponderosa* phase) 49
21. *Pseudotsuga menziesii*/*Calamagrostis rubescens* h.t. (*Calamagrostis* phase) 50
22. *Pseudotsuga menziesii*/*Juniperus communis* h.t. 53
23. *Pseudotsuga menziesii*/*Arnica cordifolia* h.t. 55
24. *Picea*/*Equisetum arvense* h.t. 59
25. *Picea*/*Clintonia uniflora* h.t. (*Clintonia* phase) 60
26. *Picea*/*Physocarpus malvaceus* h.t. 61
27. *Picea*/*Senecio streptanthifolius* h.t. (*Pseudotsuga* phase) 64
28. *Abies grandis*/*Clintonia uniflora* h.t. (*Aralia* phase) 67
29. *Thuja plicata*/*Oplopanax horridum* h.t. 74
30. *Tsuga heterophylla*/*Clintonia uniflora* h.t. (*Clintonia* phase) 75
31. *Abies lasiocarpa*/*Oplopanax horridum* h.t. 81
32. *Abies lasiocarpa*/*Clintonia uniflora* h.t. (*Aralia* phase). 83
33. *Abies lasiocarpa*/*Vaccinium caespitosum* h.t. 87
34. *Abies lasiocarpa*/*Calamagrostis canadensis* h.t. (*Calamagrostis* phase). . 89
35. *Abies lasiocarpa*/*Menziesia ferruginea* h.t. 92
36. *Abies lasiocarpa*/*Xerophyllum tenax* h.t. (*Vaccinium globulare* phase) . . 95
37. *Abies lasiocarpa*/*Xerophyllum tenax* h.t. (*Vaccinium scoparium* phase) . . 96
38. *Abies lasiocarpa*/*Clematis pseudoalpina* h.t. 102
39. *Abies lasiocarpa*/*Arnica cordifolia* h.t. 104

Page

40. Abies lasiocarpa/Carex geyeri h.t. (Pseudotsuga phase) 105
41. Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium h.t. 107
42. A Pinus albicaulis-Abies lasiocarpa h.t. 112
43. A Larix lyallii-Abies lasiocarpa h.t. 113
44. A Pinus albicaulis h.t. 114
45. Pinus contorta/Purshia tridentata h.t. 116
46. Pinus contorta/Vaccinium scoparium community type 116
47. Forested scree 122
48. Yield capability of fully stocked natural stands in relation to site index . . . 130
49. Generalized distribution of habitat types near Libby 132
50. Generalized distribution of habitat types near Missoula 133
51. Generalized distribution of habitat types in the vicinity of Butte and Philipsburg 133
52. Generalized distribution of habitat types in the vicinity of Dillon and Lima . . 134
53. Generalized distribution of habitat types on limestone substrates in the Little Belt Mountains 134
54. Generalized distribution of habitat types on nonlimestone substrates in the Little Belt Mountains 135
55. Generalized distribution of habitat types in the Gallatin and Absaroka Ranges 135
56. Generalized distribution of habitat types near Ashland 136
57. The relationship of the final Montana classification to preliminary reports and to R. and J. Daubenmire's (1968) stand data 137

TABLES:

Page

1. List of Montana forest habitat types 6
2. Elevational distribution of Pseudotsuga/Calamagrostis h.t. sample stands by phase in geographic subdivisions of Montana 48
3. Distribution of Picea phenotypes by habitat type and National Forest 57
4. Distribution of Picea/Linnaea h.t. sample stands in Montana 65
5. Estimated climatic parameters for the three subdivisions of the Abies lasiocarpa series 77
6. Distribution of ABLA/LUHI h.t. and TSME/LUHI h.t. sample stands by phase 109
7. Criteria and sources for determining site index and for estimating yield capability 128

RESEARCH SUMMARY

A land-classification system based upon potential natural vegetation is presented for the forests of Montana. It is based on an intensive 4-year study and reconnaissance sampling of about 1,500 stands. A hierarchical classification of forest sites was developed using the habitat type concept. A total of 9 climax series, 64 habitat types, and 37 additional phases of habitat types are defined. A diagnostic key is provided for field identification of the types based on indicator species used in development of the classification.

In addition to site classification, descriptions of mature forest communities are provided with tables to portray the ecological distribution of all species. Potential productivity for timber, climatic characteristics, and surface soil characteristics are also described for each type. Preliminary implications for natural resource management are provided, based on field observations and current information.

INTRODUCTION

Natural resource managers and researchers in Montana have found that existing forest cover-type classifications and site classifications have not been adequate for their needs. Forest cover-type classifications are based only on the current (often early successional) tree species. Thus, they often encompass a wide range of environmental conditions; for example, one cover type might include saplings on clearcut sites in one environment and 400-year-old climax forests in a totally different environment. Moreover, the cover type on a given site is always changing with advancing succession or sudden disturbance (such as fire, logging, insect damage, or windthrow).

Existing site classifications are usually of limited value because they are intended for use in a certain resource specialty. Also, they often have little relation to forest vegetation, even though the vegetation represents a detailed expression of the overall environment and is itself a primary object of management.

We need a better classification system for forest communities and the sites on which they develop for three reasons:

1. Communication.--Land managers and research specialists dealing with several disciplines need a common system for describing forest communities and sites.

2. Management interpretations.--Land managers must be able to make intelligent prescriptions for manipulating vegetation based on knowledge of the ecological potential of the land.

3. Research application.--Researchers can improve sampling design and layout of experiments by use of an ecological classification.

The habitat type approach to classification of forest sites was developed more than 20 years ago by Daubenmire (1952) for forests of northern Idaho and eastern Washington. His original classification, and a subsequent revision (R. and J. Daubenmire 1968), have proven useful in forest management and research (Layser 1974; Pfister 1976). Thus, after examining various approaches to forest ecosystem classification, the Intermountain Forest and Range Experiment Station and the Northern Region of the USDA Forest Service began a cooperative study in 1971 to develop this forest habitat type classification for Montana.

Objectives and Scope

The objectives of this study were:

1. To develop a habitat type classification for the forested lands of Montana based on the potential vegetation.

2. To describe the general geographic, physiographic, climatic, and edaphic (see the Glossary, appendix G, for definitions) features of each type.

3. To describe the mature forest communities (late seral) as well as the potential climax communities (associations) characteristic of each type.

4. To present information on successional development, timber productivity potential, and other biological observations of importance to forest land managers.

5. To develop and test a reconnaissance-plot method of data gathering that would permit accurate habitat type classification in a minimum period of time.

The area of Montana studied includes 10 National Forests and adjacent public and private forest lands (fig. 1). Not included were aspen grovelands of north-central Montana, coniferous forests of the Bearpaw Mountains and the Little Rockies, the ponderosa pine woodlands of the Missouri River breaks, bottomland hardwood forests of major floodplains, and minor areas of Rocky Mountain juniper woodlands scattered throughout the State. (Researchers from the University of Montana School of Forestry, are currently conducting a study of forest habitat types in north-central Montana which is scheduled for completion in December 1978.)

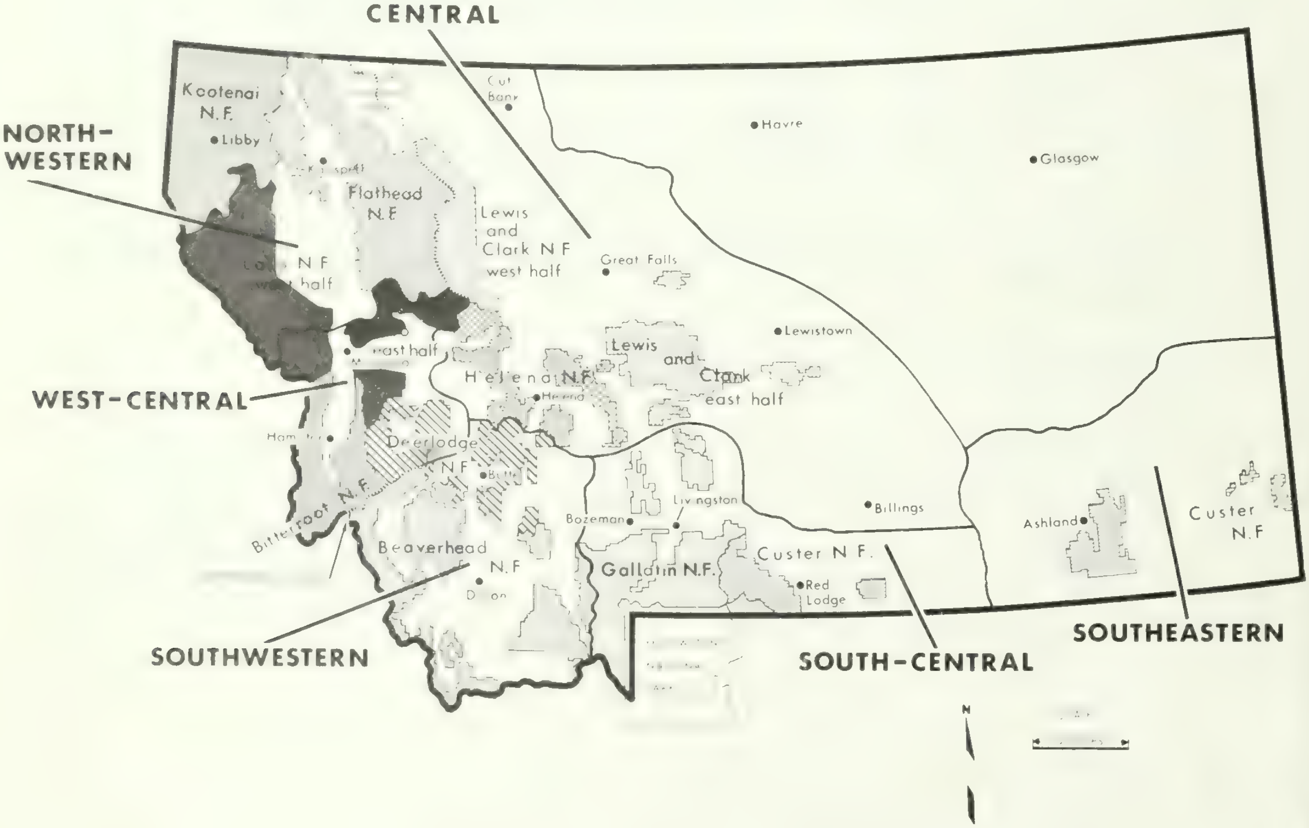

Figure 1.--Geographic subdivisions and National Forests of Montana.

METHODS

Plot Sampling

Mature stands were sampled along elevational transects at selected locations throughout forested areas of western, central, and southeastern Montana in an attempt to represent the full range of environmental conditions and later successional stages (fig. 2). Sampling was conducted on temporary 375-m^2 (about one-tenth acre) circular plots, referenced so that relocation would be possible. Transects were dispersed with the goal of essentially blanketing the Montana Rockies to the extent possible in three summers of field sampling by two to three sampling teams.

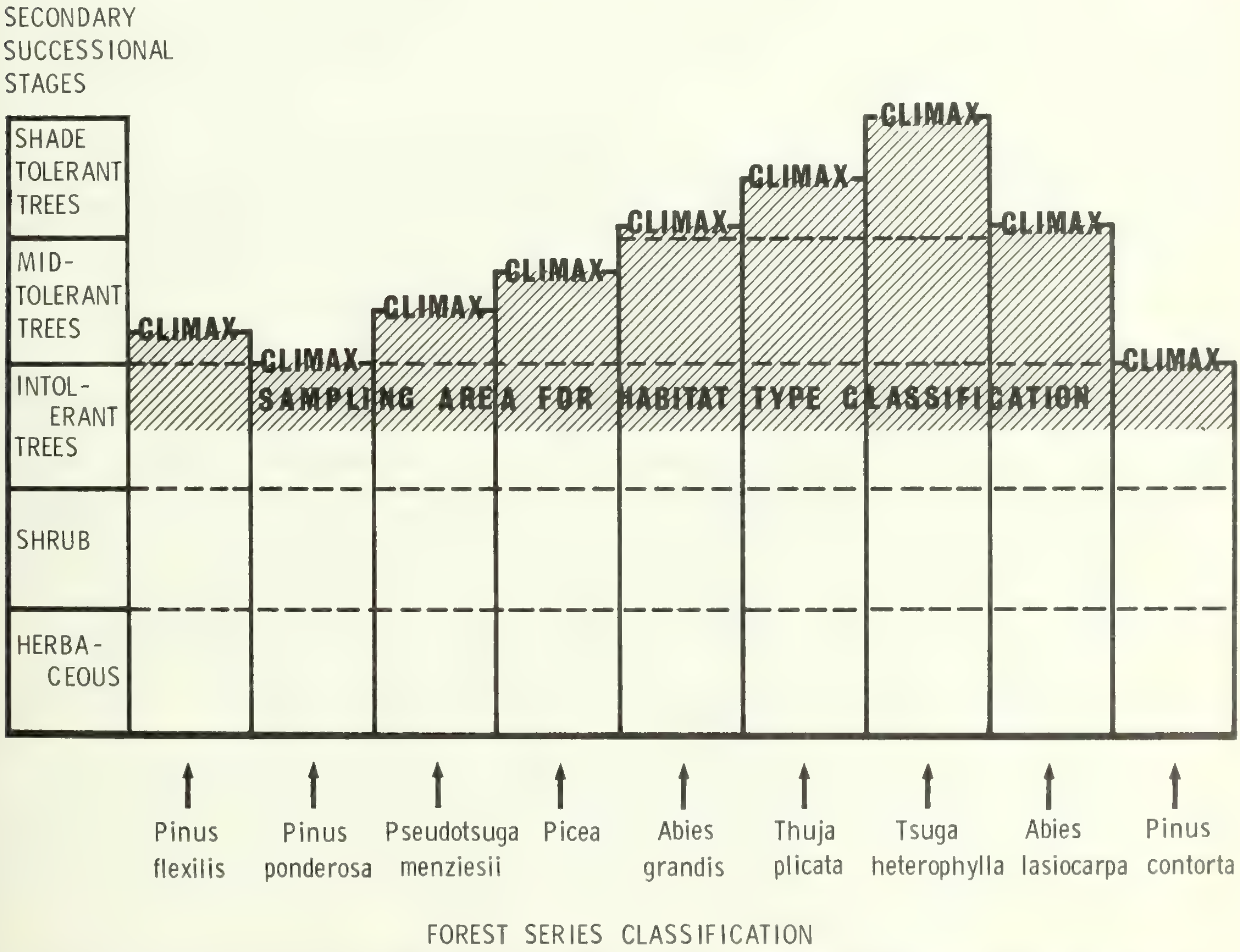

Figure 2.--Generalized successional stages of each forest series, showing the types of stands sampled as the basis for our habitat type classification.

The usual procedure of stand selection was for the team leader to travel the transect routes by vehicle, keeping a mileage log and taking notes on the patterns of forest communities. While brief stops were made to inspect undergrowth, changes in overstory and general undergrowth patterns could be observed from a moving vehicle. The extent of apparently homogeneous communities of trees and undergrowth, transitions into other communities, and topographic and edaphic features were noted. At the end of each transect, the mileage log and notes were inspected and a plan was formulated to sample representative, relatively mature forest communities on the trip back. The number of sample plots depended upon the availability of mature stands and the apparent diversity of forest communities.

Sample plots were located in representative portions of the selected stands, with special attempts made to avoid edge effects, obvious ecotones, openings, unusually dense clumps, recent disturbances, and microsites (rock outcrops, seep areas, or swales). The emphasis was on sampling stands without any preconceived idea of a classification system. Independent sampling by the three teams helped minimize the influence of possible individual biases. The transect (with stand selection) approach also had the advantage of emphasizing observations of forest community patterns on the landscape that were helpful in constructing the classification.

Random and systematic systems of stand selection were rejected because they would be very inefficient. They would oversample abundant communities and undersample scarcer ones. Also, many plots would fall on ecotones, in disturbed areas, or in heterogeneous places within a stand, providing samples of little use for developing a habitat type classification.

In each 375-m^2 plot, tree species were tallied by 2-inch d.b.h. classes. Saplings between 0.5 and 4.5 feet in height were recorded in a 50-m^2 plot. Canopy coverage of each vascular plant species was estimated by assigning one of the following seven coverage classes: + = present in stand but not in plot, T = 0 to 1 percent coverage, 1 = 1 to 5 percent, 2 = 5 to 25 percent, 3 = 25 to 50 percent, 4 = 50 to 75 percent, 5 = 75 to 95 percent, 6 = 95 to 100 percent. These classes were modified from Daubenmire (1959). Coverage class for each undergrowth species was estimated for the entire 375-m^2 plot rather than for a series of small quadrats, as is the usual procedure (R. and J. Daubenmire 1968). This approach seemed efficient for providing data on species presence and percent coverage. With a little practice and teamwork (including practice layouts of areas within the plot representing 1, 5, and 25 percent), the samplers were able to visualize and estimate coverage of grasses, forbs, shrubs, and trees using this one method. Although accuracy may be somewhat lower than that obtained by estimating coverage classes in small quadrats, the number of plots can be increased two- to fourfold, allowing for much better coverage of the forest communities. Also, the coverage-class values obtained can be used directly in association tables or ordinations.

A relatively free-growing tree of each tree species, if available, was measured for height, age, and d.b.h. to estimate site potential by species. (Suitable site trees were generally not available in the denser old-growth stands.) Maximum heights of old-growth trees were also measured.

Thicknesses of the litter, fermentation, and humus layers were measured at three locations in the plot. Samples of the upper 20 cm of mineral soil were collected for laboratory analysis along with samples of the parent material.

Observations were made on fire history, insect and disease occurrence, animal use, and environmental positions of the stand in relation to adjoining stands.

During the summer of 1971 a total of 429 stands were sampled by three teams throughout northwestern and west-central Montana (fig. 1). Data from previous studies were used whenever possible, including those collected by James R. Habeck (University of Montana) and his students, 12 of R. and J. Daubenmires' (1968) Montana plots, and 85 stands previously sampled by Pfister (unpublished reports) and Arno (1970). Although different sampling methods were used in these studies, the data could be adapted to our reconnaissance system. The combined data formed the basis for the preliminary habitat type classification of northwestern and west-central Montana in 1972, which covered the Kootenai, Flathead, Lolo, and Bitterroot National Forests and adjacent areas (fig. 1).

The following summer (1972), a total of 591 stands were sampled by three teams in central, southwestern, south-central, and southeastern Montana. These were the basis for the second preliminary classification in 1973, which covered the Deerlodge, Beaverhead, Helena, Lewis and Clark, Gallatin, and Custer National Forests and intervening areas (fig. 1).

During the field season of 1973 an additional 249 stands were sampled in areas where previous data were scant. About 50 additional stands were sampled during 1974 and 1975. The current classification of forest habitat types throughout Montana was based on a compilation of all these data.

Office Procedures

The chronological development of our classification is outlined as follows:

1. We made a subjective first grouping of possible types at the end of the 1971 and 1972 field seasons.

2. We constructed several index-of-similarity ordinations (Bray and Curtis 1957) to array the stands graphically on the basis of their species composition and coverage data. Because of the large number of stands, we grouped them by climax series (fig. 2) prior to ordination. We also gained insight to potential groupings of similar stands and the use of various species as indicators through analyzing the distributions of individual species on the ordinations.

3. We developed a classification of types and phases by comparing the first grouping with the ordination. At this time, as well as at each successive revision, we used association tables to test each stand against habitat type and phase parameters.

4. We inspected geographic location, elevation, topographic position, soils, etc., to insure that specific environmental patterns could be related to each habitat type and phase.

5. We corrected terminology for the types to express the inter-relationships of our types as clearly as possible and to correlate them with R. and J. Daubenmire (1968) whenever appropriate.

6. We used the phase as a classification unit to subdivide habitat types where appropriate. In some cases a phase represents a broad transition between two adjacent habitat types, and it may occupy major areas of the forest landscape--for example, *ABLA/CLUN* h.t., *MEFE* phase. (Because of frequent reference to habitat type names, abbreviations are used for convenience throughout this report; these are shown in table 1.) In other cases a phase represents a difference of vegetation dominance in a third layer, whereas the habitat type is defined by dominants or indicator species in two layers (e.g., *PIPO/PUTR* h.t. *AGSP* and *FEID* phases).

7. We presented the preliminary classifications, with brief descriptions of each type, at training sessions in 1972 and in 1973. These were immediately put into use on the National Forests. We solicited evaluations from users of the preliminary classification, and attempted to rectify problems, often by conducting more field sampling of problem stands.

Table 1.--*Montana forest habitat types*

[illegible]	Habitat types and phases		
	[illegible]	Scientific names	Common names
[illegible]		PINUS FLEXILIS CLIMAX SERIES	
040	PIFL/AGSP h.t.	Pinus flexilis/Agropyron spicatum h.t.	limber pine/bluebunch wheatgrass
050	PIFL/FEID h.t.	Pinus flexilis/Festuca idahoensis h.t.	limber pine/Idaho fescue
[illegible]	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
[illegible]	-FESC phase	-Festuca scabrella phase	-rough fescue phase
070	PIFL/JUCO h.t.	Pinus flexilis/Juniperus communis h.t.	limber pine/common juniper
100		PINUS PONDEROSA CLIMAX SERIES	
110	PIPO/AND h.t.[2]	Pinus ponderosa/Andropogon spp. h.t.	ponderosa pine/bluestem
130	PIPO/AGSP h.t.	Pinus ponderosa/Agropyron spicatum h.t.	ponderosa pine/bluebunch wheatgrass
140	PIPO/FEID h.t.	Pinus ponderosa/Festuca idahoensis h.t.	ponderosa pine/Idaho fescue
141	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
142	-FESC phase	-Festuca scabrella phase	-rough fescue phase
160	PIPO/PUTR h.t.	Pinus ponderosa/Purshia tridentata h.t.	ponderosa pine/bitterbrush
161	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
162	-FEID phase	-Festuca idahoensis phase	-Idaho fescue phase
170	PIPO/SYAL h.t.	Pinus ponderosa/Symphoricarpos albus h.t.	ponderosa pine/snowberry
171	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
172	-BERE phase	-Berberis repens phase	-creeping oregon grape phase
180	PIPO/PRVI h.t.	Pinus ponderosa/Prunus virginiana h.t.	ponderosa pine/chokecherry
181	-PRVI phase	-Prunus virginiana phase	-chokecherry phase
182	-SHCA phase	-Shepherdia canadensis phase	-buffaloberry phase
[illegible]		PSEUDOTSUGA MENZIESII CLIMAX SERIES	
210	PSME/AGSP h.t.	Pseudotsuga menziesii/Agropyron spicatum h.t.	Douglas fir/bluebunch wheatgrass
[illegible]	PSME/FEID h.t.	Pseudotsuga menziesii/Festuca idahoensis h.t.	Douglas fir/Idaho fescue
[illegible]	PSME/FESC h.t.	Pseudotsuga menziesii/Festuca scabrella h.t.	Douglas-fir/rough fescue
250	PSME/VACA h.t.	Pseudotsuga menziesii/Vaccinium caespitosum h.t.	Douglas fir/dwarf huckleberry
260	PSME/PHMA h.t.	Pseudotsuga menziesii/Physocarpus malvaceus h.t.	Douglas-fir/ninebark
261	-PHMA phase	-Physocarpus malvaceus phase	-ninebark phase
262	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
280	PSME/VAGL h.t.	Pseudotsuga menziesii/Vaccinium globulare h.t.	Douglas fir/blue huckleberry
281	-VAGL phase	-Vaccinium globulare phase	blue huckleberry phase
282	-ARUV phase	-Arctostaphylos uva-ursi phase	-kinnikinnick phase
283	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
290	PSME/LIBO h.t.	Pseudotsuga menziesii/Linnaea borealis h.t.	Douglas-fir/twinflower
291	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
292	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
293	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry phase
310	PSME/SYAL h.t.	Pseudotsuga menziesii/Symphoricarpos albus h.t.	Douglas-fir/snowberry
311	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
312	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
313	-SYAL phase	-Symphoricarpos albus phase	-snowberry phase
320	PSME/CARU h.t.	Pseudotsuga menziesii/Calamagrostis rubescens h.t.	Douglas fir/pinegrass
321	-AGSP phase	-Agropyron spicatum phase	-bluebunch wheatgrass phase
322	-ARUV phase	-Arctostaphylos uva-ursi phase	-kinnikinnick phase
323	-CARU phase	-Calamagrostis rubescens phase	pinegrass phase
324	PIPO phase	-Pinus ponderosa phase	-ponderosa pine phase
330	PSME/CAGE h.t.	Pseudotsuga menziesii/Carex geyeri h.t.	Douglas-fir/elk sedge
340	PSME/SPBE h.t.	Pseudotsuga menziesii/Spiraea betulifolia h.t.	Douglas fir/white spiraea
[illegible]	PSME/ARUV h.t.	Pseudotsuga menziesii/Arctostaphylos uva-ursi h.t.	Douglas fir/kinnikinnick
[illegible]	PSME/JUCO h.t.	Pseudotsuga menziesii/Juniperus communis h.t.	Douglas-fir/common juniper
370	PSME/ARCO h.t.	Pseudotsuga menziesii/Arnica cordifolia h.t.	Douglas fir/heartleaf arnica
380	PSME/SYOR h.t.[2]	Pseudotsuga menziesii/Symphoricarpos oreophilus h.t.	Douglas-fir/mountain snowberry
[illegible]		PICEA CLIMAX SERIES	
410	PICEA/EQAR h.t.	Picea/Equisetum arvense h.t.	spruce/common horsetail
420	PICEA/CLUN h.t.	Picea/Clintonia uniflora h.t.	spruce/queencup beadlily
421	-VACA phase	-Vaccinium caespitosum phase	-dwarf huckleberry phase
422	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
430	PICEA/PHMA h.t.	Picea/Physocarpus malvaceus h.t.	spruce/ninebark
440	PICEA/GATR h.t.	Picea/Galium triflorum h.t.	spruce/sweetscented bedstraw
450	PICEA/VACA h.t.	Picea/Vaccinium caespitosum h.t.	spruce/dwarf huckleberry
460	PICEA/SEST h.t.	Picea/Senecio streptanthifolius h.t.	spruce/cleft-leaf groundsel
461	-PSME phase	-Pseudotsuga menziesii phase	-Douglas-fir phase
462	-PICEA phase	-Picea phase	-spruce phase
470	PICEA/LIBO h.t.	Picea/Linnaea borealis h.t.	spruce/twinflower
480	PICEA/SMST h.t.	Picea/Smilacina stellata h.t.	spruce/starry Solomon's seal
[illegible]		ABIES GRANDIS CLIMAX SERIES	
510	ABGR/XETE h.t.	Abies grandis/Xerophyllum tenax h.t.	grand fir/beargrass
520	ABGR/CLUN h.t.	Abies grandis/Clintonia uniflora h.t.	grand fir/queencup beadlily
521	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
522	-ARNU phase	Aralia nudicaulis phase	-wild sarsaparilla phase
523	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
590	ABGR/LIBO h.t.	Abies grandis/Linnaea borealis h.t.	grand fir/twinflower
591	-LIBO phase	-Linnaea borealis phase	-twinflower phase
592	-XETE phase	-Xerophyllum tenax phase	-beargrass phase

(con.)

Table 1.--(con.)

ADP code[1]	Abbreviation	Habitat types and phases	
		Scientific names	Common names
501		THUJA PLICATA CLIMAX SERIES	
530	THPL/CLUN h.t.	Thuja plicata/Clintonia uniflora h.t.	western redcedar/queencup beadlily
531	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
532	-ARNU phase	-Aralia nudicaulis phase	-wild sarsaparilla phase
533	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
550	THPL/OPHO h.t.	Thuja plicata/Oplopanax horridum h.t.	western redcedar/devil's club
502		TSUGA HETEROPHYLLA CLIMAX SERIES	
570	TSHE/CLUN h.t.	Tsuga heterophylla/Clintonia uniflora h.t.	western hemlock/queencup beadlily
571	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
572	-ARNU phase	-Aralia nudicaulis phase	-wild sarsaparilla phase
600		ABIES LASIOCARPA CLIMAX SERIES	
700		Lower subalpine h.t.s	
610	ABLA/OPHO h.t.	Abies lasiocarpa/Oplopanax horridum h.t.	subalpine fir/devil's club
620	ABLA/CLUN h.t.	Abies lasiocarpa/Clintonia uniflora h.t.	subalpine fir/queencup beadlily
621	-CLUN phase	-Clintonia uniflora phase	-queencup beadlily phase
622	-ARNU phase	-Aralia nudicaulis phase	-wild sarsaparilla phase
623	-VACA phase	-Vaccinium caespitosum phase	-dwarf huckleberry phase
624	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
625	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
630	ABLA/GATR h.t.	Abies lasiocarpa/Galium triflorum h.t.	subalpine fir/sweetscented bedstraw
640	ABLA/VACA h.t.	Abies lasiocarpa/Vaccinium caespitosum h.t.	subalpine fir/dwarf huckleberry
650	ABLA/CACA h.t.	Abies lasiocarpa/Calamagrostis canadensis h.t.	subalpine fir/bluejoint
651	-CACA phase	-Calamagrostis canadensis phase	-bluejoint phase
653	-GATR phase	-Galium triflorum phase	-sweetscented bedstraw phase
654	-VACA phase	-Vaccinium caespitosum phase	-dwarf huckleberry phase
660	ABLA/LIBO h.t.	Abies lasiocarpa/Linnaea borealis h.t.	subalpine fir/twinflower
661	-LIBO phase	-Linnaea borealis phase	-twinflower phase
662	-XETE phase	-Xerophyllum tenax phase	-beargrass phase
663	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
670	ABLA/MEFE h.t.	Abies lasiocarpa/Menziesia ferruginea h.t.	subalpine fir/menziesia
680	TSME/MEFE h.t.	Tsuga mertensiana/Menziesia ferruginea h.t.	mountain hemlock/menziesia
690	ABLA/XETE h.t.	Abies lasiocarpa/Xerophyllum tenax h.t.	subalpine fir/beargrass
691	-VAGL phase	-Vaccinium globulare phase	-blue huckleberry phase
692	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
710	TSME/XETE h.t.	Tsuga mertensiana/Xerophyllum tenax h.t.	mountain hemlock/beargrass
720	ABLA/VAGL h.t.	Abies lasiocarpa/Vaccinium globulare h.t.	subalpine fir/blue huckleberry
730	ABLA/VASC h.t.	Abies lasiocarpa/Vaccinium scoparium h.t.	subalpine fir/grouse whortleberry
731	-CARU phase	-Calamagrostis rubescens phase	-pinegrass phase
732	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
733	-THOC phase	-Thalictrum occidentale phase	-western meadowrue phase
740	ABLA/ALSI h.t.	Abies lasiocarpa/Alnus sinuata h.t.	subalpine fir/Sitka alder
750	ABLA/CARU h.t.	Abies lasiocarpa/Calamagrostis rubescens h.t.	subalpine fir/pinegrass
770	ABLA/CLPS h.t.	Abies lasiocarpa/Clematis pseudoalpina h.t.	subalpine fir/virgin's bower
780	ABLA/ARCO h.t.	Abies lasiocarpa/Arnica cordifolia h.t.	subalpine fir/heartleaf arnica
790	ABLA/CAGE h.t.[2]	Abies lasiocarpa/Carex geyeri h.t.	subalpine fir/elk sedge
791	-CAGE phase	-Carex geyeri phase	-elk sedge phase
792	-PSME phase	-Pseudotsuga menziesii phase	-Douglas-fir phase
800		Upper subalpine h.t.s	
810	ABLA/RIMO h.t.[2]	Abies lasiocarpa/Ribes montigenum h.t.	subalpine fir/mountain gooseberry
820	ABLA-PIAL/VASC h.t.	Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium h.t.	subalpine fir-whitebark pine/ grouse whortleberry
830	ABLA/LUHI	Abies lasiocarpa/Luzula hitchcockii h.t.	subalpine fir/smooth wood-rush
831	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
832	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
840	TSME/LUHI h.t.[2]	Tsuga mertensiana/Luzula hitchcockii h.t.	mountain hemlock/smooth wood-rush
841	-VASC phase	-Vaccinium scoparium phase	-grouse whortleberry phase
842	-MEFE phase	-Menziesia ferruginea phase	-menziesia phase
890		Timberline h.t.s	
850	PIAL-ABLA h.t.s	Pinus albicaulis-Abies lasiocarpa h.t.s	whitebark pine-subalpine fir
860	LALY-ABLA h.t.s	Larix lyallii-Abies lasiocarpa h.t.s	alpine larch-subalpine fir
870	PIAL h.t.s	Pinus albicaulis h.t.s	whitebark pine
900		PINUS CONTORTA CLIMAX SERIES	
910	PICO/PUTR h.t.	Pinus contorta/Purshia tridentata h.t.	lodgepole pine/bitterbrush
920	PICO/VACA c.t.	Pinus contorta/Vaccinium caespitosum c.t.	lodgepole pine/dwarf huckleberry
930	PICO/LIBO c.t.	Pinus contorta/Linnaea borealis c.t.	lodgepole pine/twinflower
940	PICO/VASC c.t.	Pinus contorta/Vaccinium scoparium c.t.	lodgepole pine/grouse whortleberry
950	PICO/CARU c.t.	Pinus contorta/Calamagrostis rubescens c.t.	lodgepole pine/pinegrass

Total Number of Habitat Types = 64

Total Number of Habitat Types, Phase, and Pinus contorta Community Type Categories = 105

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[1] Automatic data processing codes for National Forest System use.

[2] Minor type in Montana; described in other study areas.

8. We developed the final classification (table 1) after 3 years of field testing and revising preliminary classifications, and incorporating new data. This included redefining types, rewriting the keys, checking all stands against the classification, and mutually agreeing on the types and phases. Approximately 3 percent of the sample stands did not fit the resulting classification. Many of these were ecotones or vegetational mosaics, unusual seral communities, very dense stands with little undergrowth, or minor or local associations. Some of the latter may represent potential habitat types that our data were too scant to identify.

9. We prepared a description for each habitat type, including a generalized discussion of geographic distribution, physical environmental features, key vegetational features, descriptions of phases, and the basis for their separation.

10. Where environmental characteristics and vegetative features provide a basis for predicting response to management practices, we have pointed out some of the more obvious interrelations. This classification should serve as a foundation for further development of "site-specific" management implications pertaining to several disciplines.

Taxonomic Considerations

Voucher collections of several thousand plants were made in the course of stand sampling. About 1,000 specimens of the better collections have been deposited in the herbarium of the Forestry Sciences Laboratory, Missoula. Most of the plants were identified to species, but some nonflowering specimens could not be identified to or beyond the genus level. Peter F. Stickney of the Missoula herbarium verified many of the field identifications. Specimens of some of the more difficult groups were sent to the USDA Forest Service herbarium in Fort Collins, Colorado, where Dr. F. J. Hermann made determinations for *Carex* and Dr. Charles Feddema identified the remaining groups. Determinations for *Penstemon* were made by Dr. David V. Clark, Colorado Mountain College, Glenwood Springs; Dr. Rupert C. Barneby, Greenport, Long Island, made the identifications for *Astragalus* and *Oxytropis*. The presence table (appendix C-2) provides a complete list of species found in at least five of the nearly 1,500 stands sampled. Nomenclature generally follows Hitchcock and Cronquist (1973).

The nature of the survey method often required that field identification be made on material in vegetative, sterile, or other than optimal condition for taxonomic separation. This prevented positive identification of some closely related species; in such cases, specimens were grouped under the most prevalent species for the region.

A few species presented special taxonomic problems. Although *Vaccinium membranaceum* is reported for Montana (Hitchcock and others 1955-69), essentially all of our *Vaccinium globulare-V. membranaceum* collections appeared to be *V. globulare*.

Vaccinium myrtillus often intergrades extensively with *V. scoparium* and perhaps also with *V. globulare* in Montana. Our tabular data represent *V. myrtillus* as identified by the strictest taxonomic criteria.

Clematis pseudoalpina and *C. tenuiloba* are evidently restricted to similar environments and they intergrade to such a confusing extent that we lumped them under *C. pseudoalpina*.

Special attention needs to be given to the distinction between *Pinus albicaulis* and *P. flexilis* in Montana. *Pinus albicaulis* grows at high elevations all across the Montana Rockies, whereas *P. flexilis* is common below the forest zone along or east of the Continental Divide extending up to midelevations on droughty sites. Cones of *Pinus albicaulis* are purple and *disintegrate on the tree* (leaving only broken scales on the ground), whereas those of *P. flexilis* turn from green to brown and *remain intact on the* *ground* for a few years. *Pinus albicaulis* is a common forest component whose reproduction, usually as stagnant saplings, may extend down to midelevations. *Pinus flexilis* is rarely a component of dense forests, and seldom reproduces in stands dominated by other species.

Most *Picea* populations in Montana are the result of *P. engelmannii* X *P. glauca* hybridization (Daubenmire 1974; Habeck and Weaver 1969). However, our observations and cone scale measurements indicate recognizable differences in the degree of hybridization. The cone scales of *Picea glauca* are broadest near the tip, which is rounded and smooth. The cone scales of *P. engelmannii* are broadest near the base, narrowing at the tip, and having a wavy, crinkled, papery margin. *P. engelmannii* twigs are usually finely pubescent, whereas those of *P. glauca* are normally without hairs. Recognition of these and other taxonomic differences (Daubenmire 1974) is important for silvicultural practices and future research efforts involving *Picea*.

Synecological Perspective and Terminology

Definition and Explanation of Habitat Type

All land areas potentially capable of producing similar plant communities at climax may be classified as the same habitat type (Daubenmire 1968b). The climax plant community, because it is the end result of plant succession, reflects the most meaningful integration of the environmental factors affecting vegetation. Thus, each habitat type represents a relatively narrow segment of environmental variation and delineates a certain potential for vegetative development. One habitat type may support a variety of disturbance-induced, or seral, plant communities, but the vegetative succession will ultimately produce similar plant communities at climax throughout the type.

The climax community type, or association, provides a logical name for the habitat type--for example, *Pseudotsuga menziesii/Calamagrostis rubescens*. The first part of this name is based on the climax tree species, which is usually the most shade-tolerant tree adapted to the site. We call this level of classification the series and it encompasses all habitat types having the same dominant tree at climax. The second part of the habitat type name is based on the dominant or characteristic undergrowth species in the climax community type.

Use of climax community types to name habitat types does not imply that we have an abundance of climax vegetation in the present landscape. Actually, most vegetation in the landscape reflects some form of disturbance and various stages of succession towards climax. Nor do climax community type names imply that management is for climax vegetation; in fact, seral species are frequently preferred for timber and wildlife browse production. Furthermore, this method does not require the presence of a climax stand to identify the habitat type. It can be identified during most intermediate stages of succession by comparing the relative reproductive success of the tree species present with known successional trends and by observing the existing undergrowth vegetation. Successional trends toward climax usually appear to progress more rapidly in the undergrowth than in the tree layer. In very early stages of secondary succession, the habitat type can be identified by comparing the site with similar adjacent ones having mature stands.

Not all units of land will fit neatly into the habitat type system. As in most biological classifications, intergrades, or transitional areas will be encountered. However, these situations occupy a small percentage of land and need not greatly detract from the utility of a habitat type classification.

The main advantage of habitat types in forest management is that they provide a permanent and ecologically-based system of land stratification. Each habitat type encompasses a certain amount of environmental variation, but the variation within a habitat type should be less than that between types. In addition, habitat types provide a classification of climax plant communities. Plant succession should be generally predictable for each habitat type, and similar responses to management treatments can be expected on units of land within the same type.

Habitat Types Versus Continuum Philosophy

A vigorous debate has been carried on for many years by ecologists who study plant communities--i.e., phytosociologists. Although several philosophies have been developed to interpret plant-community organization, two of them are often the center of debate: (1) the advocates of typal communities argue that distinct vegetation types develop at climax and are repeated over the landscape where environmental conditions are similar; (2) continuum advocates argue that even at climax, vegetation, like environmental conditions, varies continuously over the landscape (Daubenmire 1966; Cottam and McIntosh 1966; Vogl 1966). Some of those who accept the typal communities philosophy may view habitat type classification much the same as they view the taxonomic classification of the plant kingdom. Continuum advocates may regard habitat type classifications as an attempt to make categories by drawing fine lines at intervals along a complex vegetational continuum. Collier and others (1973) presented these contrasting philosophies and advocated an intermediate viewpoint.

While this debate may be of interest academically, it need not preoccupy natural resource managers and field biologists who need a logical, ecologically-based classification with which to work. We have proceeded under the philosophy that if a "continuum" does exist, then we would subdivide it into classes. Our primary objective has remained to develop a logical classification that reflects the natural patterns found on the landscape. Local conditions that deviate from this classification can still be described in terms of how they differ from the nearest typal description.

Some Synecological Relationships

R. and J. Daubenmire (1968) presented a detailed discussion of many synecological concepts that apply here also. Like the Daubenmires, we found that overstory and undergrowth unions generally do not have identical range limits. Some of the undergrowth unions that the Daubenmires defined in combination with only one climax overstory union were found more broadly distributed in Montana forests. Thus, we have *Xerophyllum tenax* as an undergrowth type with *Pseudotsuga menziesii* and *Abies grandis* as well as *A. lasiocarpa* and *Tsuga mertensiana*. In these situations, distinguishing habitat types primarily on the basis of climax tree species leads to recognizing a larger number of habitat types. Other aspects of undergrowth-overstory relationships are discussed in the series and habitat type descriptions.

Our stand tables and observations also support R. and J. Daubenmire's (1968) contention that the "principle of competitive exclusion" is rarely achieved in natural stands because it requires several centuries without disturbance. However, there is a *trend* toward dominance by the most shade-tolerant tree species. This trend is most evident on mesic sites, where the seral and climax species show the greatest differences in shade tolerance. It becomes less evident as climax species such as *Tsuga, Thuja,* and *Abies grandis* reach their geographic range limits eastward across the Montana Rockies. In such peripheral stands, these species do not always maintain their characteristic ability to exclude other species at climax (R. and J. Daubenmire 1968). The trend toward monospecific dominance is also less evident where forests do not develop a closed canopy. Stand analysis indicates that certain conifers persist in a minor climax or even coclimax status along with the dominant climax species in several habitat types. These relationships are portrayed in appendix B. In the interest of simplicity the habitat type name usually reflects only one major climax species. Exceptions are *ABLA-PIAL/VASC*, *PIAL-ABLA*, and *LALY-ABLA* habitat types (table 1).

Although transitional areas or ecotones between habitat types can be interpreted as being broad or narrow, our approach was to interpret them as narrowly as possible. In this way, more of the land surface is definable to habitat type and less is in ecotonal categories that may be impractical for use in resource management.

In discussing the relationship of a habitat type to certain environmental features, we have followed the polyclimax concept of Tansley (1935). Thus, a *climatic climax* develops on deep loamy soils of gently undulating relief; an *edaphic climax* differs from the climatic climax due to extreme soil conditions such as coarse texture or poor drainage; and a *topographic climax* reflects compensating effects of topography on microclimate. The *topoedaphic climax* is a convenient way to designate deviation from a climatic climax due to combined effects of edaphic and topographic features. Some habitat types reflect only one type of climax, but the majority of them occur in two or more of the above categories in response to interaction of environmental factors.

THE PHYSICAL SETTING

Topography and Geology

The western one-third of Montana--roughly, the area west of a line running from Red Lodge to East Glacier Park--is prominently mountainous with intervening valleys. However, isolated mountain ranges occur as far as 150 to 200 miles east of that line (fig. 3) in the Montana Great Plains. In northwestern and west-central Montana (fig. 1), valley base elevations generally range between 2,000 and 4,000 feet; these valleys are either forested or grassland. The major mountain ranges rise to elevations of 7,000 to 9,000 feet. These mountains support extensive forests up to subalpine levels, and there is a small amount of area above the alpine timberline.

In central Montana the broad, grassy intermountain valleys are generally 4,000 to 5,000 feet in elevation; the major mountain ranges, which are often less rugged than ranges to the west, rise to between 7,000 to 9,000 feet.

In the southwestern and south-central portions of the State the grassy intermountain valleys are high, generally 4,500 to 6,500 feet, and major mountain ranges usually rise to 10,000 feet or higher. The Absaroka and Beartooth Ranges have rather extensive plateau-like areas above timberline.

The surface geologic formation throughout most of northwestern Montana is the Precambrian Belt Series, consisting primarily of quartzites and argillites. The Idaho and Boulder Batholiths comprise the Bitterroot Range west of the Bitterroot Valley and much of the southern Sapphire and Anaconda-Pintlar Ranges as well as the Continental Divide from Butte to Helena. Composition is predominantly granitic with inclusions of gneiss and schist. Volcanic and sedimentary rocks (both limestone and nonlimestone) constitute most of the remainder of the Montana Rockies. Many of the mountain areas near or east of the Continental Divide are geologically complex in contrast to areas farther west (Perry 1962).

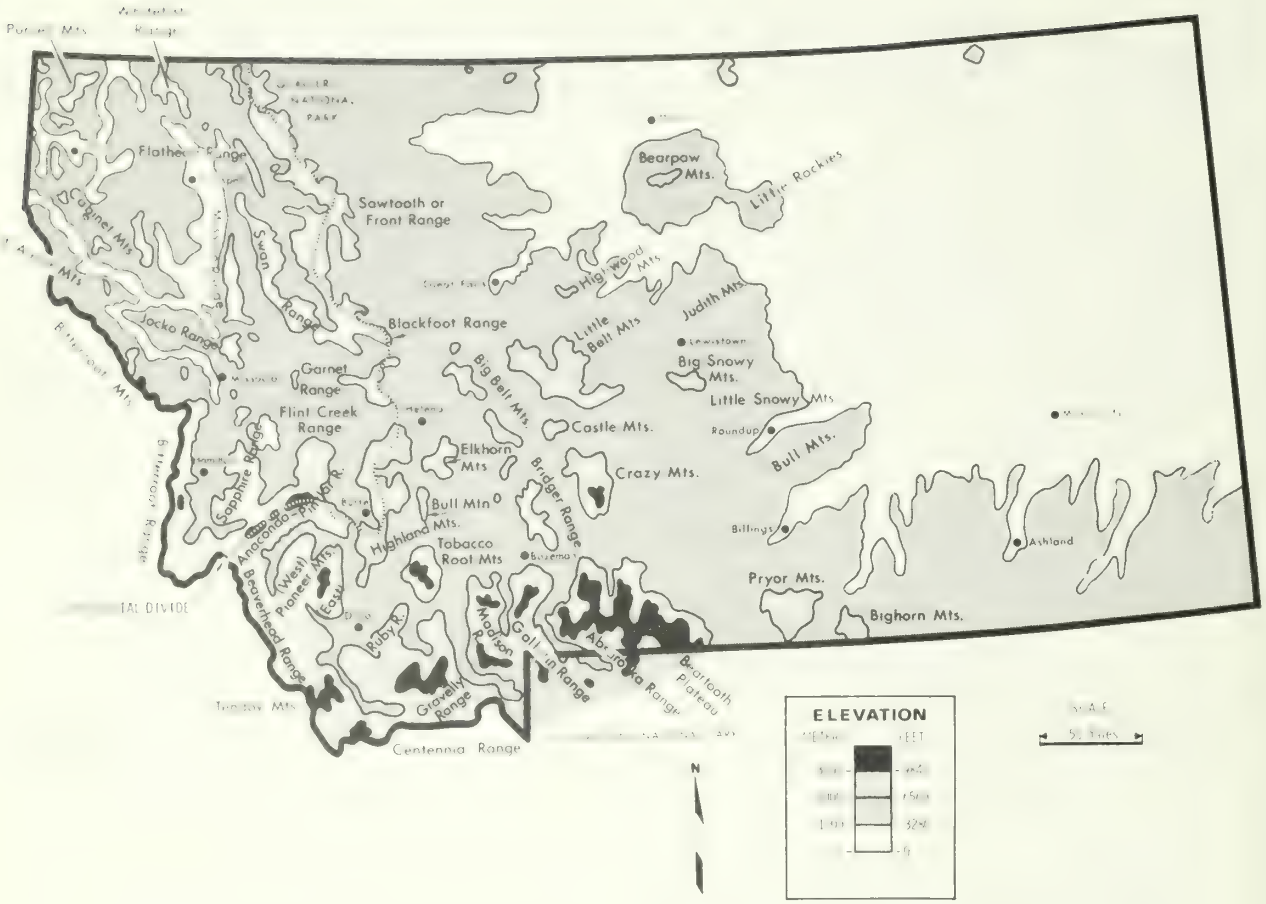


Figure 3.--Distribution of mountain ranges in Montana

Most of the prominent valleys in the Montana Rockies contain a layer of alluvium deposited by streams and glacial action. The majority of these areas support grassland, riparian, or cultivated vegetation, although substantial areas in northwestern Montana valleys support forests.

Contrasting plant communities develop where limestone and noncalcareous substrates meet in many areas east of the Continental Divide in Montana. Bamberg and Major (1968), Despain (1973), Patten (1963), and others have described vegetational patterns related to limestone substrates in and adjacent to Montana. Herbert Holdorf--soil scientist on the Lewis and Clark National Forest at Great Falls, Montana--has also noted the relationships of various geological substrates to soil and forest development. Goldin (1976) has enumerated Holdorf's observations in addition to documenting the relationship of forest habitat types to three substrates (limestone, granite, and quartzite) in the Garnet Range east of Missoula. Several correlations of forest vegetation to limestone and other calcareous rocks became apparent during the current study and are discussed in later sections.

Soils

In general, Montana forest soils are quite rocky, reflecting their mountainous setting. Because steep topography and rocky soils are so prevalent, sites capable of supporting a climatic climax are scarce over much of the forested landscape.

In northern Idaho, R. and J. Daubenmire (1968) observed that soil mantles on leeward slopes were better developed than those on windward slopes because of wind-deposited loess and volcanic ash from the west. This correlation applies also in Montana west of the Continental Divide although it is usually much less pronounced.

Nimlos (1963) described the prominent great soil groups found in Montana west of the Continental Divide. Brown Podzolic soils occupy the moister forest sites--"areas of more than 25 inches of mean annual precipitation on fine textured calcareous materials and on areas of more than 17 inches on coarse textured, acid materials." He further stated that a Bir horizon 4 to 18 inches thick is the most diagnostic feature of these soils. Brown Podzolic soils are apparently also associated with moist forest types east of the Divide in Montana (Western Land Grant Univ. 1964). Such soils are evidently associated with the *Tsuga*, *Thuja*, *Abies grandis*, and *A. lasiocarpa* climax series we well as wetter habitat types in the *Picea*, *Pinus contorta*, and *Pseudotsuga* series.

Gray Wooded soils (Nimlos 1963; Western Land Grant Univ. 1964) are associated with the drier forest types in Montana. The average annual precipitation of these sites, which support the *Pinus ponderosa* and drier part of the *Pseudotsuga* series, is about 15 to 20 inches.

Chernozems are also likely to be found in the open forests where steppe understory vegetation has a dominant soil forming effect.

According to the maps, descriptions, and nomenclature of the new *Soil Taxonomy* (USDA Soil Conservation Service 1975) the major subgroups of soils in Montana forests are:

1. Cryoborolls--on lower elevation slopes with grass-dominated undergrowth.
2. Cryoboralfs--on midelevation slopes in central and southern Montana.
3. Cryandepts--on midelevation slopes in areas of western Montana with volcanic ash deposits.
4. Cryochrepts--on higher elevation and steep slopes throughout mountains of Montana.
5. Torriorthents--shallow soils on the steep mountain slopes, badlands, and rolling plains in central and southeastern Montana.

Climate and Microclimate

The Continental Divide exerts a marked influence on Montana's climate (U.S. Dep. Commerce 1971), resulting in marked vegetation differences across the State. The area west of the Divide has an inland climate strongly modified by moisture-laden air masses from the North Pacific Ocean. Mild, cloudy weather prevails in all seasons except midsummer. Precipitation is rather evenly distributed throughout the year, except for a dry period in July and August. In the northwest portion of the State, where the maritime influence is strongest, some of the lower elevations have a sufficiently moist (average annual precipitation greater than 30 inches) and mild climate to support vegetation similar to that of the Pacific Coast mountains (*Tsuga* and *Thuja* series). Eastward, Pacific Coast species drop out of the flora as oceanic moisture diminishes with each crossing of a mountain range.

East of the Divide the climate is decidedly continental. It is characterized by warm summers with a high proportion of the precipitation falling between May and September and winter conditions that have invasions of subzero Arctic air followed by warm dry Chinook winds.

Elevation also has a major effect on climate and thus on vegetation patterns. Except in extreme northwestern Montana, lowlands are semiarid and support either grassland or very dry forest types. Mountains are much cooler and often receive two to three times as much annual precipitation, most of it coming in the form of snow. Above 8,000 feet in northern Montana and 9,500 feet in southern Montana, forests give way to alpine tundra. About 25 mountain ranges in the State support some tundra, which develops on sites having mean July temperatures of less than 50 degrees F. (Arno 1970). Thus, the lower elevational limits of coniferous forests are controlled primarily by moisture, while the upper elevational limits are controlled primarily by temperature.

Topographic features also have a strong influence on microclimate, as R. and J. Daubenmire (1968) pointed out. North and south exposures have strongly contrasting environments because of differences in insolation, snow accumulation, and soil development. Cold air drains down into mountain valleys at night and forms "frost pockets" behind topographic constrictions. These sites are occupied by distinctive vegetation, some of it characteristic of higher elevations.

SUCCESSIONAL STATUS OF MONTANA FORESTS

Fire History

Recognition of the important role played by lightning-caused fires in Montana forests has been growing, especially in the last few decades (Wellner 1970). During our sampling, we observed and recorded evidence of past fires on about 1,000 plots. Such evidence consists of partially-healed fire scars at the base of old trees or stumps, charred material on or in the ground, and presence of new stands or age-classes of seral species.

Some of the most abundant species in Montana forests are fire-adapted seral trees (Starker 1934; Wellner 1970). Mature *Larix occidentalis*, *Pinus ponderosa*, and *Pseudotsuga menziesii* have thick basal bark which makes them very resistant to fire. *Pinus contorta* and *Thuja* show moderate resistance to death from ground fire. Most other species (e.g., *Abies*, *Tsuga*, *Picea*) are likely to be killed by most fires, because of thin bark and susceptibility to rot entering fire-caused wounds.

The vast majority of all sample stands showed evidence of wildfire within the past two centuries, despite deliberate selection of the oldest and least-disturbed stands. The few stands that showed no evidence of fire in the past 200 years were usually at high elevations or on very moist sites.

In general, the *Pinus flexilis*, *Pinus ponderosa* and drier *Pseudotsuga* habitat types showed evidence of light ground fires at intervals averaging less than 30 years. Moister *Pseudotsuga* habitat types and *Abies lasiocarpa* habitat types showed much longer fire-free intervals, and the fires often resulted in formation of new stands, or at least in the addition of a new age class in surviving stands.

Arno (1976) cross-sectioned fire scars on old growth *Pinus ponderosa, Pseudotsuga menziesii, Pinus contorta, Larix occidentalis,* and *Pinus albicaulis* in several habitat types in three areas of the Bitterroot National Forest. He found that prior to 1900 average fire frequencies had been about 10 years in *Pinus ponderosa/* and *Pseudotsuga/* bunchgrass habitat types, 16-19 years in most other *Pseudotsuga* habitat types, 27 years in lower subalpine *Abies lasiocarpa* habitat types, and 30-33 years in upper subalpine and timberline habitat types. Many individual trees and stumps in *Pseudotsuga* habitat types at various locations in west-central Montana have scars from 10 or more fires in a period of 200 or 250 years; however, few fires occurred in the last 50 years.

Gabriel (1976) studied the fire history of *Pinus contorta*-dominated forests in an area of the Bob Marshall Wilderness, Flathead National Forest. He found evidence that fire had been rather frequent and that it burned at various intensities. Other fire frequency studies have been made by Houston (1973) in northern Yellowstone National Park and by Loope and Gruell (1973) in the Jackson Hole area of northwestern Wyoming. East of the Continental Divide, in the vast forests dominated by *Pinus contorta,* we commonly found stands where many of the trees had scars indicating they had survived one to three ground fires. If *Pinus contorta* stands survive more than about 100 years, they often become susceptible to attack and mortality from mountain pine beetle (*Dendroctonus ponderosae*); the resulting large buildup of dry fuels invites an intense conflagration (Roe and Amman 1970). *Pinus contorta* stands showing no evidence of having survived a fire were in most cases even-aged and evidently had become established after an intense forest fire.

Relative coverages and species composition in the tree layer and undergrowth often change dramatically after an intense fire. West of the Continental Divide, double or triple burns have sometimes removed the conifer seed source. Thus, a shrub-field stage of succession (composed of such species as *Amelanchier alnifolia, Salix scouleriana, Acer glabrum, Ceanothus velutinus, Prunus* spp., and *Physocarpus malvaceus*) may dominate the site for half a century or longer.

Grazing History

In general, domestic grazing has not had a pronounced impact upon the forest vegetation in Montana. In northwestern and west-central portions of the State, however, some of the most open, low-elevation forests (i.e., *Pinus ponderosa* series and drier habitat types in the *Pseudotsuga* series) and streamside areas have been moderately to heavily grazed by cattle, horses, or sheep. Hillsides too steep for cattle have not been grazed heavily, due to the decline in sheep raising in the past 20-30 years. Grazing has been extended into moister forest types in some localities, such as the Montana-Idaho Divide west of Superior, where sheep were historically grazed. Also, clearcuts and other heavily logged areas are often used by cattle. Still, a large proportion of the west-side forest has apparently never been grazed by domestic stock.

East of the Continental Divide, there is a higher proportion of dry, open forest having bunchgrasses and other palatable forage. Also, the forest is broken by extensive mountain grasslands suitable for summer range. Grazing is often extended up the major forested valleys where streamside vegetation and luxuriant meadows are common. Although lower east-side forests are often moderately to heavily grazed, the denser, high-elevation forests receive little use except as bedding areas where they border subalpine grasslands. Sheep grazing of alpine tundra on the Montana side of the Beartooth Plateau was halted in the 1950's, and plant recovery has been noticeable. Large flocks of sheep continue to graze the Wyoming portion of this alpine area.

Logging History

About half of the forest land in Montana had not been logged as of 1973. This generalization applies to both sides of the Continental Divide. However, in some historical mining localities such as Butte and Helena, extensive forests were cut between about 1870 and 1920. In the Highland Mountains south of Butte, for example, the forests were logged nearly to the alpine timberline.

Early settlement west of the Continental Divide brought extensive clearing of forests in the major valleys for farming and ranching. Heavy cutting was also associated with early mining and railroading activities. Commercial lumbering has long been practiced west of the Divide, and it has expanded considerably with the establishment of a diversified forest products industry in the past two decades. A great deal of virgin forest land both east and west of the Divide has been roaded and logged since 1950, but several wilderness and primitive areas have also been established and many of the remaining roadless areas are being studied for possible inclusion in the National Wilderness System.

THE HABITAT TYPE CLASSIFICATION

We defined a total of 64 forest habitat types for Montana. Although this may seem like an unusually large number, the environmental diversity across the State warrants recognition of many types.

Figure 4 shows a generalized elevational distribution of the various climax series encountered in the Montana Rockies, except for the *Pinus contorta* series. These are

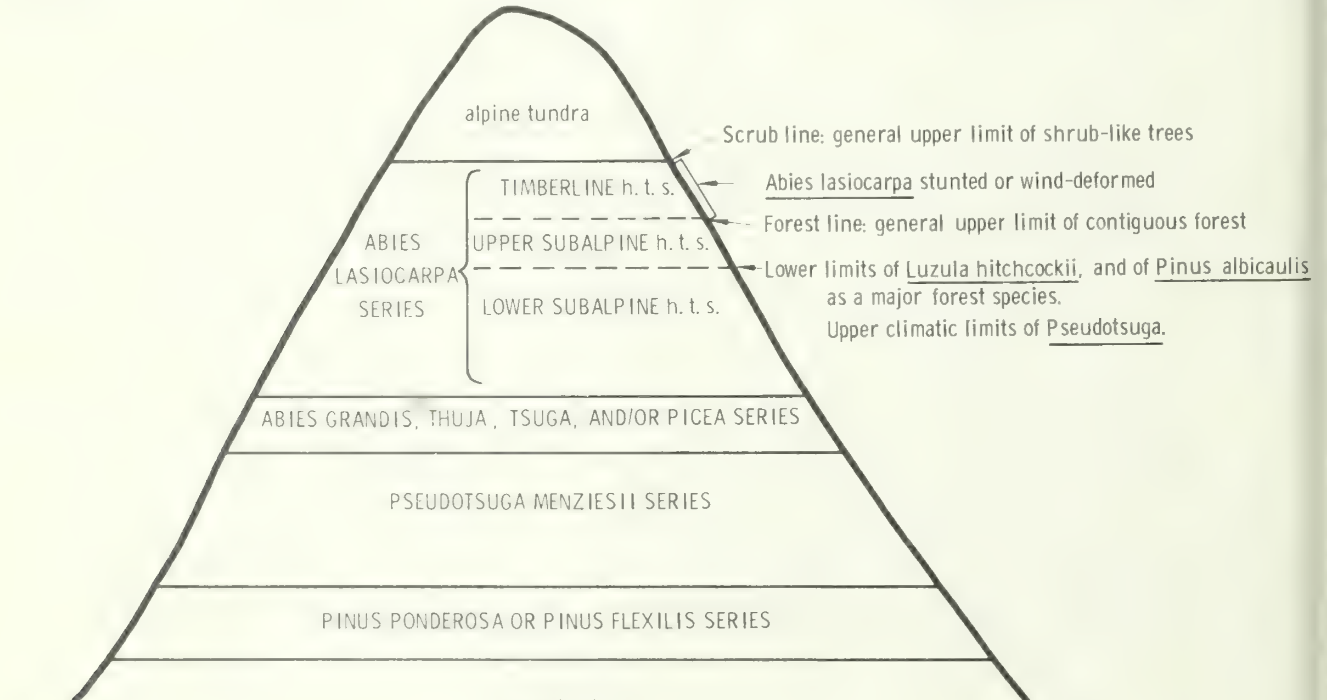

alpine tundra
Scrub line: general upper limit of shrub-like trees
TIMBERLINE h. t. s.
Abies lasiocarpa stunted or wind-deformed
Forest line: general upper limit of contiguous forest
ABIES LASIOCARPA SERIES
UPPER SUBALPINE h. t. s.
Lower limits of Luzula hitchcockii, and of Pinus albicaulis as a major forest species.
Upper climatic limits of Pseudotsuga.
LOWER SUBALPINE h. t. s.
ABIES GRANDIS, THUJA, TSUGA, AND/OR PICEA SERIES
PSEUDOTSUGA MENZIESII SERIES
PINUS PONDEROSA OR PINUS FLEXILIS SERIES
grasslands

Figure 4.--Generalized climax zonation of the coniferous forest series in Montana.

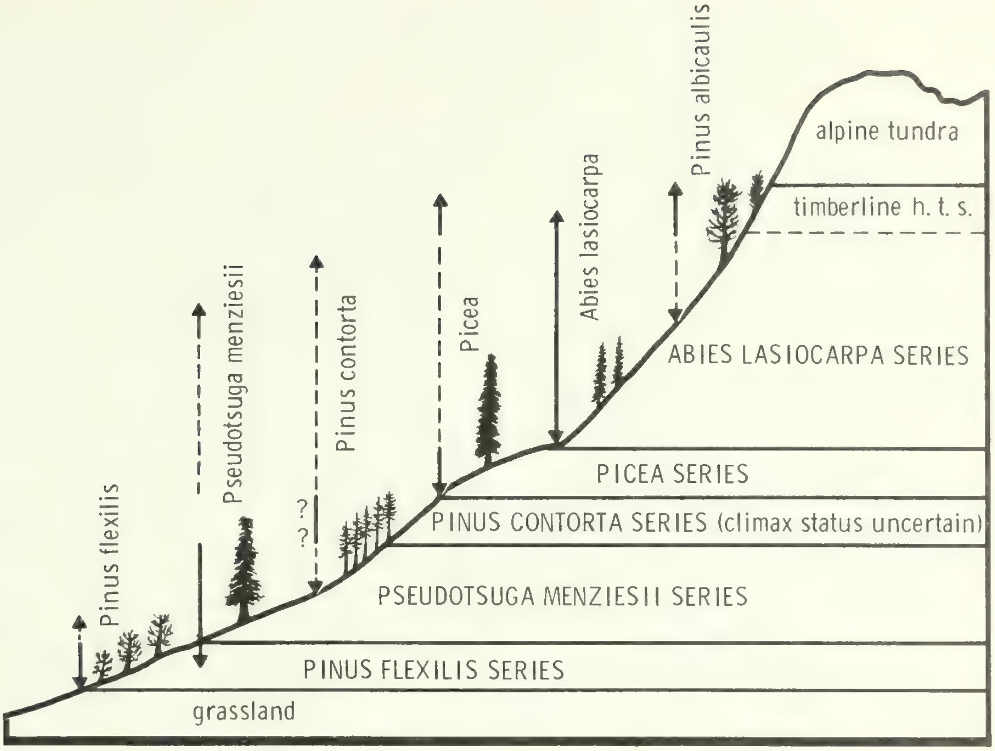


Figure 5.--Generalized distribution of forest trees in southwestern and south-central Montana. Arrows show the relative elevational range of each species; solid portion of the arrow indicates where a species is the potential climax and dashed portion shows where it is seral.

discussed in approximately the order shown here, going from dry, warm (lower elevation) sites to increasingly colder and more moist conditions.

These series do not all occur in all parts of the Montana Rockies. For instance, in much of southwestern and south-central Montana, the *Pinus ponderosa*, *Abies grandis*, *Thuja plicata*, and *Tsuga heterophylla* series are absent. The distribution of individual tree species and the climax series relationships for that area are shown in figure 5.

The greatest number of climax series is found in certain parts of northwestern Montana. Figure 6 shows a composite distribution of the most diverse zonation found in that area.

The total classification is listed in table 1 for convenient reference. Scientific names, abbreviated names, and common names are listed in the habitat type writeups, table 1, and the checklist, appendix F. Common names are not used in the text because they vary from place to place and could lead to confusion. With the need for frequent references to habitat type names in the text, some form of abbreviation seemed desirable. We have used a four-letter abbreviation consisting of the first two letters of the genus name and the first two letters of the species name. Although these abbreviations may be unfamiliar initially, we have found them to be readily accepted by professional foresters and biologists as a substitute for common names.

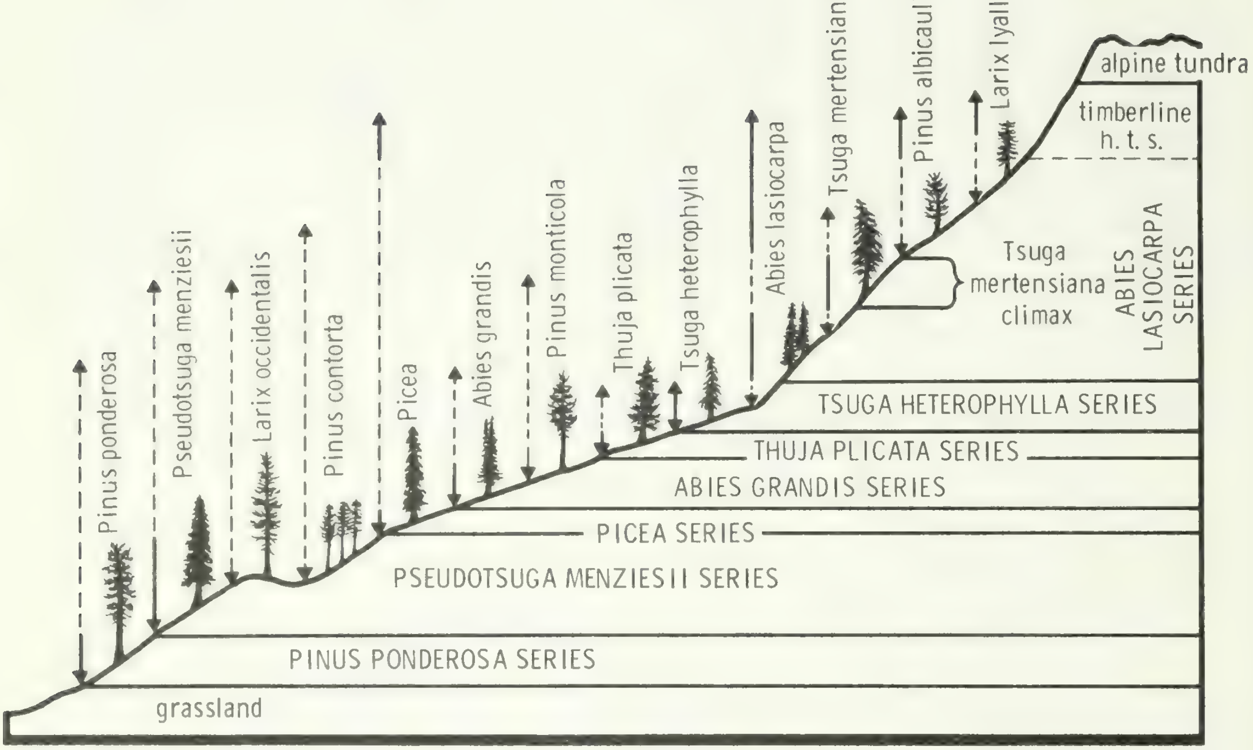


Figure 6.--Distribution of forest trees in an area of northwestern Montana. Arrows show the relative elevational range of each species; solid portion of the arrow indicates where a species is the potential climax and dashed portion shows where it is seral.

The classification is presented in the following order:

1. *Key to the habitat types (fig. 7).*--The first step in correct identification of the habitat type is becoming familiar with the instructions for use of the key. Next comes identification of the potential climax series, followed by identification of the habitat type and then the phase.

2. *Series description.*--Many habitat type characteristics are summarized at the series level, rather than repeating general similarities in vegetation and habitat characteristics in the habitat type descriptions.

3. *Habitat type description.*--This information summarizes geographic range, vegetation, phases, and general management implications.

Pinus flexilis Series

Distribution.--In Montana *Pinus flexilis* distribution is related to the continental climatic regime; thus the species seldom occurs very far west of the Continental Divide. The *Pinus flexilis* series is found on some of the driest sites capable of supporting trees.

Figure 7. — Key to climax series, habitat types, and phases.

READ THESE INSTRUCTIONS FIRST!

1. Use this key for stands with a mature tree canopy that are not severely disturbed by grazing, logging, forest fire, etc. (If the stand is severely disturbed or in an early successional stage, the habitat type can best be determined by extrapolating from the nearest mature stand occupying a similar site.)

2. Accurately identify and record canopy coverages for all indicator species (appendix F).

3. Check plot data in the field to verify that the plot is representative of the stand as a whole. If not, take another plot.

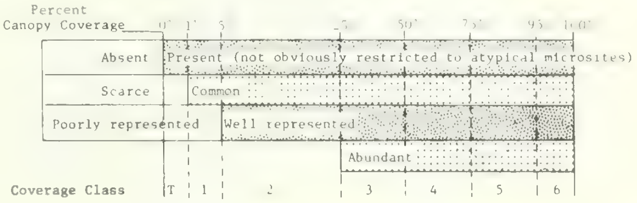
4. Identify the correct potential climax tree species in the SERIES key. (Generally, a tree species is considered reproducing successfully if 10 or more individuals per acre occupy or will occupy the site.)

5. Within the appropriate series, key to HABITAT TYPE by following the key literally. Determine PHASE by matching the stand conditions with the phase descriptions for the type. (The first phase description that fits the stand is the correct one.)

6. Use the definitions diagramed below for canopy coverage terms in the key. If you have difficulty deciding between types, refer to constancy and coverage data (appendix C-1) and the habitat type descriptions.

7. In stands where undergrowth is obviously depauperate (unusually sparse) because of dense shading or duff accumulations, adjust the above definitions to the next lower coverage class (e.g., well represented >1%, common >0%).

8. Remember, the key is NOT the classification! Validate the determination made using the key by checking the written description.



KEY TO CLIMAX SERIES

(DO NOT PROCEED UNTIL YOU HAVE READ THE INSTRUCTIONS!)

1. Habitats on steep slopes (30^o)composed primarily of unstable fine rock; undergrowth sparse, poorly developed and quite variable. . . . SCREE (p. 121)
1. Habitats on sites with some soil development and stability; undergrowth rather well developed and somewhat uniform. 2

2. Tsuga heterophylla present and reproducing successfully . . . . TSUGA HETEROPHYLLA SERIES (item G)
2. Tsuga heterophylla not the indicated climax 3

3. Thuja plicata present and reproducing successfully. . . . . THUJA PLICATA SERIES (item F)
3. Thuja plicata not the indicated climax. 4

4. Abies grandis present and reproducing more successfully than Abies lasiocarpa. . . . . ABIES GRANDIS SERIES (item E)
4. Abies grandis not the indicated climax. 5

5. Abies lasiocarpa, Tsuga mertensiana, or Larix lyallii present and reproducing successfully, or Pinus albicaulis the dominant tree . . . . . ABIES LASIOCARPA SERIES (item I)
5. Not as above. 6

6. Picea present and reproducing successfully. . . . . PICEA SERIES (item D)
6. Picea not the indicated climax. 7

7. Pinus flexilis a successfully reproducing dominant; often sharing that status with Pseudotsuga . . . . PINUS FLEXILIS SERIES (item A)
7. Pinus flexilis absent or clearly seral. 8

8. Pseudotsuga menziesii present and reproducing successfully. . . . . . PSEUDOTSUGA MENZIESII SERIES (item C)
8. Pseudotsuga menziesii not the indicated climax. 9

9. Pure Pinus contorta stands, with little evidence as to potential climax. . . . . PINUS CONTORTA SERIES (item H)
9. Pinus contorta absent; Pinus ponderosa the indicated climax . . . . PINUS PONDEROSA SERIES (item B)

A. Key to Pinus flexilis Habitat Types

1. Festuca idahoensis well represented or F. scabrella common. . . . . PINUS FLEXILIS/FESTUCA IDAHOENSIS h.t. (p. 25)
    a. Festuca scabrella common. . . . . FESTUCA SCABRELLA phase
    b. F. scabrella scarce . . . . FESTUCA IDAHOENSIS phase
1. F. idahoensis poorly represented and F. scabrella scarce. 2

2. Agropyron spicatum well represented . . . . PINUS FLEXILIS/AGROPYRON SPICATUM h.t. (p. 24)
2. A. spicatum poorly represented, Juniperus communis (or J. horizontalis) well represented . PINUS FLEXILIS/JUNIPERUS COMMUNIS h.t. (p. [illegible]

[illegible]

[illegible]

3. Purshia tridentata well represented . . . . PINUS PONDEROSA/PURSHIA TRIDENTATA h.t.(p.

[illegible]

5. Agropyron spicatum well represented . . . . PINUS PONDEROSA/AGROPYRON SPICATUM h.t.(p. 30)
5. A. spicatum poorly represented; Andropogon spp. well represented . . . . . . PINUS PONDEROSA/ANDROPOGON h.t.(p. 30)

[illegible]

[illegible]inium caespitosum present . . . . PSEUDOTSUGA MENZIESII/VACCINIUM CAESPITOSUM h.t.(p. 39)

2. Physocarpus malvaceus or Holodiscus discolor well represented . . PSEUDOTSUGA MENZIESII/PHYSOCARPUS MALVACEUS h.t.(p. 41)
   a. [illegible]
   b. Physocarpus and/or Holodiscus dominate the undergrowth. . . . . . PHYSOCARPUS MALVACEUS phase

3. Linnaea borealis common . . . . PSEUDOTSUGA MENZIESII/LINNAEA BOREALIS h.t.(p. 44)
   a. Symphoricarpos albus well represented . . . . SYMPHORICARPOS ALBUS phase
   b. [illegible]
   c. [illegible]

4. Vaccinium globulare or Xerophyllum tenax well represented . . . . PSEUDOTSUGA MENZIESII/VACCINIUM GLOBULARE h.t.(p. 43)
   a. Arctostaphylos uva-ursi and Pinus ponderosa common . . . . ARCTOSTAPHYLOS UVA-URSI phase
   b. Xerophyllum common . . . . XEROPHYLLUM TENAX phase
   c. Not as above . . . . VACCINIUM GLOBULARE phase

5. Symphoricarpos albus well represented . . . . PSEUDOTSUGA MENZIESII/SYMPHORICARPOS ALBUS h.t.(p. 45)
   a. Bunchgrasses well represented in old-growth stands . . . . AGROPYRON SPICATUM phase
   b. [illegible]
   c. [illegible]

6. Calamagrostis rubescens well represented . . . . PSEUDOTSUGA MENZIESII/CALAMAGROSTIS RUBESCENS h.t.(p. 47)
   a. [illegible]
   b. Arctostaphylos uva-ursi common; sites capable of supporting Pinus ponderosa and not too dry for Pinus contorta (or Larix occidentalis) . . . . ARCTOSTAPHYLOS UVA-URSI phase
   c. [illegible]
   d. [illegible]

7. Carex geyeri well represented . . . . PSEUDOTSUGA MENZIESII/CAREX GEYERI h.t.(p. 51)

8. Arctostaphylos uva-ursi well represented and Pinus ponderosa present . . . . PSEUDOTSUGA MENZIESII/ARCTOSTAPHYLOS UVA-URSI h.t.(p. 52)
8. [illegible] limits of Pinus ponderosa 9

9. Juniperus communis (or J. horizontalis) dominates the undergrowth . . PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t.(p. 53)

10. Spiraea betulifolia well represented . . . . PSEUDOTSUGA MENZIESII/SPIRAEA BETULIFOLIA h.t.(p. 52)
10. S. betulifolia poorly represented 11

11. Arnica cordifolia or Antennaria racemosa the dominant undergrowth . . PSEUDOTSUGA MENZIESII/ARNICA CORDIFOLIA h.t.(p. 54)

[illegible]

13. Symphoricarpos oreophilus well represented and Festuca idahoensis scarce . . . . PSEUDOTSUGA MENZIESII/SYMPHORICARPOS OREOPHILUS h.t.(p. 55)

14. Festuca idahoensis common; Pinus ponderosa scarce . . . . PSEUDOTSUGA MENZIESII/FESTUCA IDAHOENSIS h.t.(p. 38)

[illegible]

D. Key to *Picea* Habitat Types

1. *Equisetum* spp. abundant	PICEA/EQUISETUM ARVENSE h.t.(p. 58)
Equisetum spp. not abundant	2
2. *Clintonia uniflora*, *Cornus canadensis*, or *Aralia nudicaulis* present (sites in northwestern Montana).	PICEA/CLINTONIA UNIFLORA h.t.(p. 59)
a. *Vaccinium caespitosum* present	VACCINIUM CAESPITOSUM phase
b. *V. caespitosum* absent	CLINTONIA UNIFLORA phase
2. Not as above	3
3. *Physocarpus malvaceus* well represented	PICEA/PHYSOCARPUS MALVACEUS h.t.(p. 61)
3. *Physocarpus* poorly represented	4
4. Two of these moist-site forbs present: *Galium triflorum*, *Streptopus amplexifolius*, *Actaea rubra*	PICEA/GALIUM TRIFLORUM h.t.(p. 62)
4. Not as above	5
5. *Vaccinium caespitosum* present	PICEA/VACCINIUM CAESPITOSUM h.t.(p. 62)
5. *V. caespitosum* absent	6
6. *Linnaea borealis* common	PICEA/LINNAEA BOREALIS h.t.(p. 64)
6. *Linnaea* scarce	7
7. *Smilacina stellata* or *Thalictrum occidentale* present	PICEA/SMILACINA STELLATA h.t.(p. 65)
7. Not as above; *Senecio streptanthifolius* present; undergrowth depauperate	PICEA/SENECIO STREPTANTHIFOLIUS h.t.(p. 63)
a. *Pseudotsuga menziesii* common	PSEUDOTSUGA MENZIESII phase
b. *Pseudotsuga* scarce (stands above its elevational limits)	PICEA phase

E. Key to *Abies grandis* Habitat Types

1. *Clintonia uniflora* present	ABIES GRANDIS/CLINTONIA UNIFLORA h.t.(p. 67)
a. *Aralia nudicaulis*, *Gymnocarpium dryopteris*, or *Athyrium filix-femina* common	ARALIA NUDICAULIS phase
b. *Xerophyllum tenax* well represented	XEROPHYLLUM TENAX phase
c. Not as above	CLINTONIA UNIFLORA phase
1. *Clintonia* absent	2
2. *Linnaea borealis* common	ABIES GRANDIS/LINNAEA BOREALIS h.t.(p. 69)
a. *Xerophyllum tenax* well represented	XEROPHYLLUM TENAX phase
b. *Xerophyllum* poorly represented	LINNAEA BOREALIS phase
2. *Linnaea* scarce; *Xerophyllum* common	ABIES GRANDIS/XEROPHYLLUM TENAX h.t.(p. 69)

F. & G. Key to *Thuja* and *Tsuga heterophylla* Habitat Types

1. *Oplopanax horridum* well represented	THUJA PLICATA/OPLOPANAX HORRIDUM h.t.(p. 73)
1. *Oplopanax* poorly represented	2
2. *Tsuga heterophylla* present and reproducing successfully	TSUGA HETEROPHYLLA/CLINTONIA UNIFLORA h.t.(p. 74)
a. *Aralia nudicaulis*, *Gymnocarpium dryopteris*, or *Athyrium filix-femina* common	ARALIA NUDICAULIS phase
b. Not as above	CLINTONIA UNIFLORA phase
2. *Tsuga heterophylla* absent or not reproducing successfully	THUJA PLICATA/CLINTONIA UNIFLORA h.t.(p. 71)
a. *Aralia nudicaulis*, *Gymnocarpium dryopteris*, or *Athyrium filix-femina* common	ARALIA NUDICAULIS phase
b. *Menziesia ferruginea* common	MENZIESIA FERRUGINEA phase
c. Not as above	CLINTONIA UNIFLORA phase

H. Key for *Pinus contorta* Communities

1. *Clintonia uniflora* present	ABIES LASIOCARPA/CLINTONIA UNIFLORA h.t.(p. 82)
1. *Clintonia* absent	2
2. Two of these moist-site forbs present: *Galium triflorum*, *Actaea rubra*, *Streptopus amplexifolius*	ABIES LASIOCARPA/GALIUM TRIFLORUM h.t.(p. 86)
2. Not as above	3
3. *Calamagrostis canadensis* well represented	ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS h.t.(p. 88)
3. *C. canadensis* poorly represented	4
4. *Vaccinium caespitosum* present	PINUS CONTORTA/VACCINIUM CAESPITOSUM comm. type(p. 118)
4. *V. caespitosum* absent	5
5. *Linnaea borealis* common	PINUS CONTORTA/LINNAEA BOREALIS comm. type(p. 119)
5. *Linnaea* scarce	6
6. *Xerophyllum tenax* common	ABIES LASIOCARPA/XEROPHYLLUM TENAX h.t.(p. 94)
6. *Xerophyllum* scarce	7
7. *Vaccinium globulare* well represented	ABIES LASIOCARPA/VACCINIUM GLOBULARE h.t.(p. 97)
7. *V. globulare* poorly represented	8
8. *Vaccinium scoparium* well represented	PINUS CONTORTA/VACCINIUM SCOPARIUM comm. type(p. 119)
8. *V. scoparium* poorly represented	9
9. *Calamagrostis rubescens* well represented	PINUS CONTORTA/CALAMAGROSTIS RUBESCENS comm. type(p. [illegible])
9. *C. rubescens* poorly represented	10
10. *Carex geyeri* well represented	ABIES LASIOCARPA/CAREX GEYERI h.t.(p. 105)
10. *C. geyeri* poorly represented	11
11. *Juniperus communis* (or *J. horizontalis*) the major undergrowth	PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t.(p. 53
11. Not as above; *Purshia tridentata* present	PINUS CONTORTA/PURSHIA TRIDENTATA h.t.(p. 117)

[illegible]

[illegible]

Not as above

[illegible]

[illegible] Oplopanax poorly represented . . . . [illegible]

[illegible]

VACCINIUM SCOPARIUM phase

XEROPHYLLUM TENAX phase

[illegible]

Tsuga mertensiana well represented . . . . TSUGA MERTENSIANA/MENZIESIA FERRUGINEA h.t. (p. 94)

ABIES LASIOCARPA/MENZIESIA FERRUGINEA h.t. (p. [illegible]

ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS h.t. (p. 88)

[illegible] phase

VACCINIUM [illegible] phase

CALAMAGROSTIS CANADENSIS phase

[illegible] represented

ABIES LASIOCARPA/GALIUM TRIFLORUM h.t. (p. 8[illegible]

Not as above . . . . ABIES LASIOCARPA/VACCINIUM CAESPITOSUM h.t. (p. 87)

[illegible] caespitosum absent.

Linnaea borealis common . . . . ABIES LASIOCARPA/LINNAEA BOREALIS h.t. (p. 90)

a. Xerophyllum tenax [illegible] XEROPHYLLUM TENAX phase

[illegible] VACCINIUM SCOPARIUM phase

[illegible] LINNAEA BOREALIS phase

ABIES LASIOCARPA/ALNUS SINUATA h.t. (p. [illegible]

[illegible] A. sinuata poorly represented

11. Tsuga mertensiana well represented . TSUGA MERTENSIANA/XEROPHYLLUM TENAX h.t. (p. 97)

ABIES LASIOCARPA/XEROPHYLLUM TENAX h.t. (p. 94)

VACCINIUM SCOPARIUM phase

VACCINIUM GLOBULARE phase

ABIES LASIOCARPA/VACCINIUM GLOBULARE h.t. (p. 97)

13. Vaccinium scoparium (including V. myrtillus) well [illegible] . ABIES LASIOCARPA/VACCINIUM SCOPARIUM h.t. (p. 98)

CALAMAGROSTIS RUBESCENS phase

THALICTRUM OCCIDENTALE phase

VACCINIUM SCOPARIUM phase

ABIES LASIOCARPA/CLEMATIS PSEUDOALPINA h.t. (p. [illegible]

ABIES LASIOCARPA/CALAMAGROSTIS RUBESCENS h.t. (p. 101)

ABIES LASIOCARPA/CAREX GEYERI h.t. (p. 10[illegible]

PSEUDOTSUGA MENZIESII phase

CAREX GEYERI phase

ABIES LASIOCARPA/ARNICA CORDIFOLIA h.t. (p. [illegible]

PINUS ALBICAULIS h.t. [illegible]

LARIX LYALLII-ABIES LASIOCARPA h.t. (p. [illegible]

PINUS ALBICAULIS-ABIES LASIOCARPA h.t. (p. [illegible]

Calamagrostis canadensis, Senecio triangularis, or [illegible] well represented . . ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS h.t. (p. 88)

C. canadensis, S. triangularis, and Ledum poorly represented

[illegible] well represented

TSUGA MERTENSIANA/LUZULA HITCHCOCKII h.t. (p. [illegible]

MENZIESIA FERRUGINEA phase

VACCINIUM SCOPARIUM phase

ABIES LASIOCARPA/LUZULA HITCHCOCKII h.t. (p. [illegible]

MENZIESIA FERRUGINEA phase

VACCINIUM SCOPARIUM phase

ABIES LASIOCARPA-PINUS ALBICAULIS/VACCINIUM SCOPARIUM h.t. (p. 107)

[illegible] Carex geyeri well represented

ABIES LASIOCARPA/RIBES MONTIGENUM h.t. (p. 106)

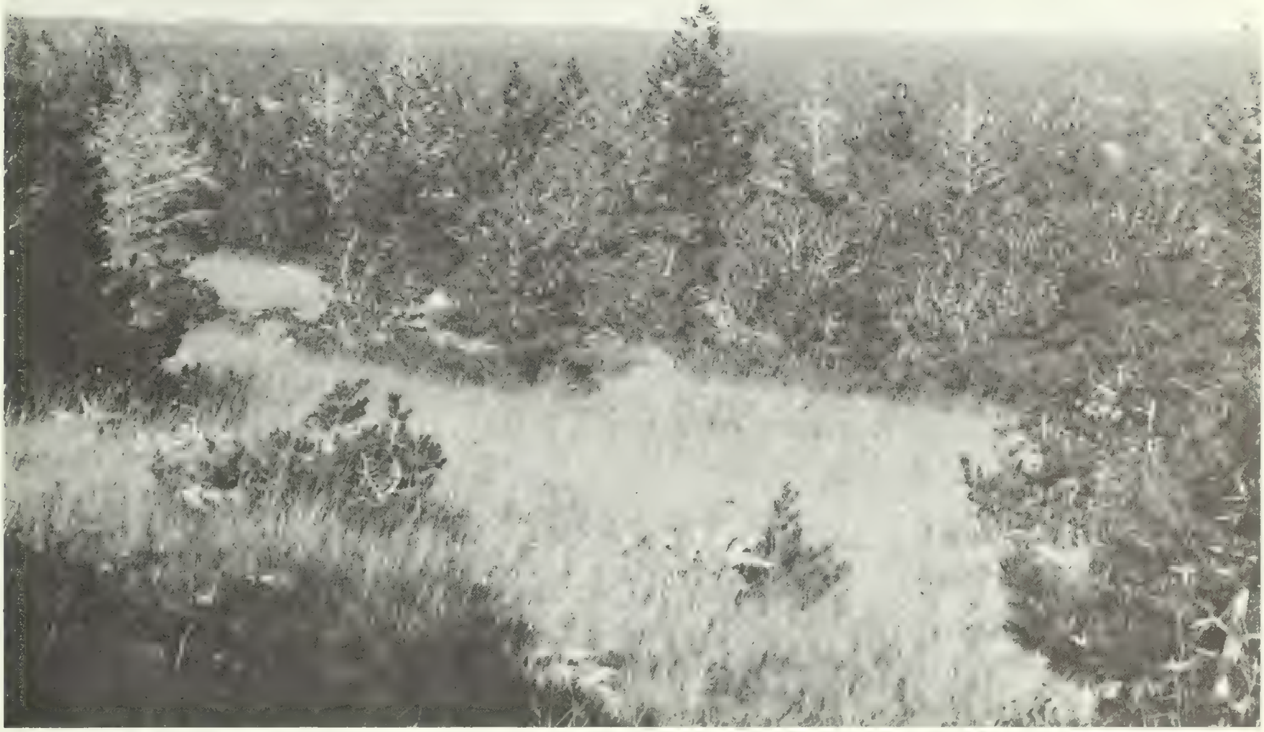


Figure 8.--Pinus flexilis/Festuca idahoensis *h.t.* *(*F. scabrella *phase) at the western edge of the Great Plains, northwest of Choteau in central Montana (5,900 feet elev.). Trees are a mixture of* Pinus flexilis *and stunted* Pseudotsuga.

Pinus flexilis dominates stands that extend eastward from the foothills into the adjacent Great Plains (fig. 8). Low tree height (about 20 feet) and the topographic position of such stands below the forest proper is suggestive of the "coniferous woodland" or pinyon-juniper zone of the southwestern United States.

Pinus flexilis stands are also found on steep, dry, rocky mountain slopes at lower to midelevations (fig. 9). Adjacent drier sites are grassland, while cooler, more moist exposures often support the *Pseudotsuga* series. In this situation the *Pinus flexilis* series generally represents a topographic or edaphic climax.

Vegetation.--Pinus flexilis is either the only tree species present or it is codominant with *Pseudotsuga* and reproducing successfully with no indication of being replaced at climax. *Agropyron spicatum* dominates the undergrowth in stands at lower elevations on dry, rocky sites. With increasing moisture, *Pseudotsuga* becomes codominant with *Pinus flexilis*, and undergrowth is dominated by *Festuca idahoensis* or *F. scabrella*. At the highest elevations occupied by this series, bunchgrasses give way to undergrowth dominated by *Juniperus communis, J. horizontalis*, and dry-site forbs.

Soil/Climate.--Sites are generally rocky with intermittent shallow duff accumulation (appendix D-1). Surface soils are shallow gravelly loams to gravelly silts, nearly neutral, and generally derived from limestone or other calcareous parent materials. Surface horizons are typically dark-colored, reflecting the strong influence of grasses and forbs on soil development.

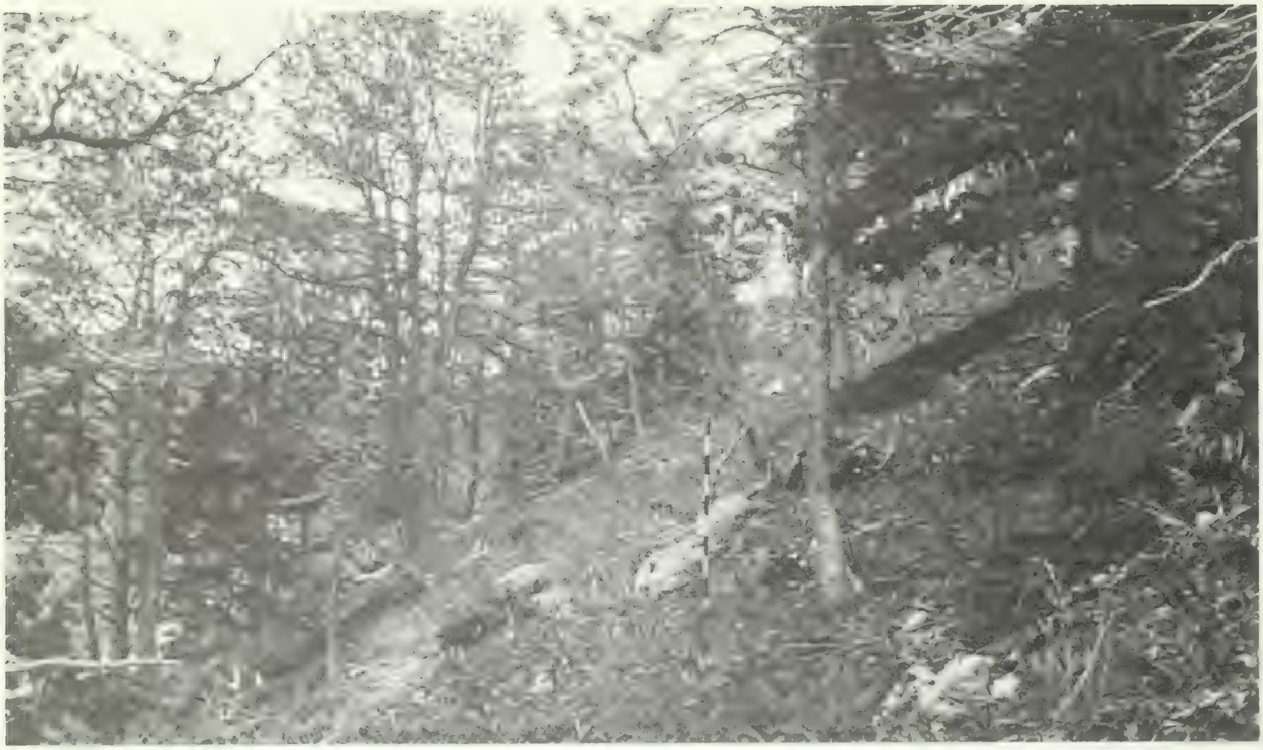


Figure 9.--Pinus flexilis/Juniperus communis *h.t. high on a southwest exposure (7,650 feet elev. near Red Lodge in south-central Montana.* Pseudotsuga *is subordinate to* Pinus flexilis; *the substrate is calcareous.*

Weather stations at Townsend and Black Leaf apparently have a climate typical of the *Pinus flexilis* series. Some climatic parameters for these stations are shown in appendix D-2.

Productivity/Management.--Timber productivity is very low (appendix E-4) in the severe environments of this series. Site indexes of both *Pinus flexilis* and *Pseudotsuga menziesii* are very low, and stockability limitations are reflected by low basal areas in natural stands (appendix E-1). Old growth trees rarely reach 50 feet height (appendix E-2).

The forage value of the undergrowth for domestic stock or wildlife varies among the habitat types. The overstory may provide important escape cover for wildlife, especially on sites adjacent to grasslands.

Pinus flexilis seeds are large, and constitute an important food source for certain bird and rodent species.

Other studies.--Other *Pinus flexilis* habitats have been described southward in the Rocky Mountains: in Utah by Ellison (1954), Pfister (1972a), and Ream (1964); in Wyoming by Reed (1969), Despain (1973), and Wirsing (1973); and in central Idaho by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station).

Pinus flexilis/Agropyron spicatum h.t.
(*PIFL/AGSP*; limber pine/bluebunch wheatgrass)

Distribution.--The *PIFL/AGSP* h.t. is widely distributed east of the Continental Divide on dry, rocky sites adjacent to or within the grassland zone. Elevations of our sample stands ranged from 4,400 feet on the Helena to 6,600 feet on the Beaverhead National Forest (appendix A).

Vegetation.--*Pinus flexilis* is the dominant climax tree, often with *Juniperus scopulorum* as a major climax associate. *Pseudotsuga* is occasionally present in minor amounts. In a few areas, *Pinus ponderosa* is a climax associate.

Dry-site forbs and graminoids (grasses, *Carex*, *Juncus*, and other grasslike plants) of the contiguous grasslands accompany *Agropyron spicatum* in the undergrowth. These include *Hesperochloa kingii, Oryzopsis hymenoides, Koeleria cristata, Bouteloua gracilis, Yucca glauca,* and species of *Opuntia, Phlox, Draba, Hymenoxys, Hymenopappus,* and *Liatris.*

Soil.--We found this type only on sedimentary parent materials, primarily limestone and sandstone (appendix D-1). The average pH was high (7.1), reflecting the calcareous parent materials. Ground surfaces had averages of 18 percent exposed rock and 25 percent bare soil. Duff accumulation averaged only 1 cm on the remaining area.

Fire history.--Wildfires are apparently of low intensity because of sparse vegetation and rocky, broken terrain.

Productivity/Management.--Although these sites are often adjacent to heavily-grazed grasslands, domestic livestock do not use the *PIFL/AGSP* h.t. heavily. Low forage production and steep slopes limit potential for domestic grazing.

Elk sign was not observed on any of our plots. Mule deer use was light.

Timber productivity is very low (appendix E-4). Maximum heights of old-growth *Pinus flexilis* are only 30 to 35 feet. Basal areas are also very low (appendix E).

Other studies.--*PIFL/AGSP* stands in south-central and southeastern Montana on the Beaverhead and Custer National Forests often contain *Hesperochloa kingii.* These stands appear to be related to part of the *Pinus flexilis/Hesperochloa kingii* h.t. described for the Medicine Bow Mountains of Wyoming (Wirsing 1973).

Pinus flexilis/Festuca idahoensis h.t.
(*PIFL/FEID*; limber pine/Idaho fescue)

Distribution.--The *PIFL/FEID* h.t. is found east of the Continental Divide on dry, wind-exposed slopes; in some localities it covers substantial acreages. Elevations of sample plots ranged from 4,800 feet at the base of the Front Range west of Choteau to 8,200 feet on the Beaverhead National Forest.

Vegetation.--*Pinus flexilis* is a successfully reproducing dominant in old-growth stands, often sharing climax status with *Pseudotsuga. Juniperus scopulorum* is a minor component of some stands.

The undergrowth is dominated by bunchgrasses, primarily *Festuca idahoensis, F. scabrella,* and *Agropyron spicatum.* Associated species include *Geum triflorum, Allium cernuum, Artemisia frigida, Achillea millefolium, Lithospermum ruderale, Koeleria cristata,* and *Balsamorhiza sagittata.* Forb and bunchgrass coverages are much higher here than in the *PIFL/AGSP* h.t. (appendix C-1). Occasionally *Juniperus communis* is well represented in stands on sites transitional toward the *PIFL/JUCO* h.t.

Festuca idahoensis (FEID) phase.--This widely distributed phase denotes the portion of the h.t. where *Festuca scabrella* is scarce.

Festuca scabrella (FESC) phase.--This phase is found exclusively in central Montana (fig. 1). Locally it is extensive, especially on the east slope of the Rockies in the vicinity of Choteau and in the foothills on the east side of the Big Belt Mountains north of White Sulphur Springs. *Festuca scabrella* is common, and codominates with *F. idahoensis*. Average canopy coverage for bunchgrasses is notably higher (47 percent) than in the *FEID* phase (30 percent). Where the two phases occur together, the *Festuca scabrella* phase is on the cooler, less rocky sites.

Soil.--More than one half the sample stands were on calcareous parent materials (appendix D-1). Surface soils were slightly basic on the calcareous substrates and neutral to acidic on other substrates. Textures were gravelly, ranging from sandy loams to silts. Moderate amounts of surface rock (12 percent) and bare soil (8 percent) were exposed in the *FEID* phase. Duff was shallow (1 cm) in both phases.

Fire history.--Evidence of wildfire was more conspicuous here than in the *PIFL/AGSP* h.t. However, fires did not appear to markedly modify plant composition.

Productivity/Management.--*PIFL/FEID* h.t. seems to be capable of supporting considerable use by domestic stock. However, use was light in the areas we sampled. Immediately north of the Montana border, Moss and Campbell (1947) found that heavy grazing of *Festuca scabrella*-dominated grasslands resulted in greatly decreasing the coverage of that species while increasing the coverage of *Festuca idahoensis*.

Pellets and shed antlers from both deer and elk indicate moderate to heavy use as winter range. Deer also appear to use this type as summer range. Overstory density is adequate to provide cover and escape for big game without shading out desirable forage and browse species. Where use by domestic stock and big game conflicts, management priorities need to be determined.

Pseudotsuga is often a major dominant on these sites, but timber productivity is very low (appendix E-4). Average maximum heights for *Pseudotsuga* and *Pinus flexilis* are only 40 to 45 feet (appendix E-2).

Other Studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have described the *FEID* phase of *PIFL/FEID* h.t. in east-central Idaho, and Cooper (1975) found a minor representation of similar communities in northwestern Wyoming.

Pinus flexilis/Juniperus communis h.t.
(*PIFL/JUCO*; limber pine/common juniper)

Distribution.--The *PIFL/JUCO* h.t. is widespread in dry mountain areas east of the Continental Divide. It is common in the Pryor Mountains and on the east slopes of the Beartooth Mountains near Red Lodge. It is primarily restricted to limestone or other calcareous parent materials on severe south to southwest exposures and ridges. Occasionally it is found on north aspects adjacent to *Festuca idahoensis* grasslands. Elevations of sample stands were 4,600 to 6,000 feet in central Montana, increasing to 7,600 to 8,300 feet in the south-central portion of the State.

Vegetation.--*Pinus flexilis* is a successfully reproducing dominant in old-growth stands, often sharing climax status with *Pseudotsuga*. Rarely, *Pinus albicaulis* is a minor climax associate.

This undergrowth is composed primarily of dry-site shrubs and forbs. *Juniperus communis* or *J. horizontalis* are well represented and bunchgrasses are scarce. Forbs commonly found are *Clematis pseudoalpina, Arnica cordifolia, Aster conspicuus, Campanula rotundifolia, Galium boreale, Astragalus miser, Anemone multifida,* and *Frasera speciosa.*

Soil.--Soils had high pH values (average 7.1), reflecting the predominance of calcareous parent materials (appendix D-1). Bare soil (1 percent) and rock exposure (6 percent) were less than, and duff accumulations (3 cm) were greater than in other habitat types in this series. Textures were gravelly loams to gravelly clay loams.

Fire history.--Old-growth stands sampled showed little evidence of fire, suggesting a low frequency of wildfires in this habitat type. Overstories are all-aged, with continual replacement of dead old growth.

Productivity.--Timber productivity is low to very low (appendix E). Cattle use appears to be moderate. Our observations also indicate that mule deer make substantial use of the type from spring through fall.

Other studies.--The *PIFL/JUCO* h.t. appears to be similar to part of Wirsing's (1973) *Pinus flexilis/Hesperochloa kingii* h.t. described for the Medicine Bow Mountains of Wyoming.

Pinus ponderosa Series

Distribution.--In many areas of the Montana Rockies, the first forest zone above the grassland is *Pinus ponderosa* climax. This species endures dry environments more successfully than other native conifers--except *Pinus flexilis* and *Juniperus scopulorum*, which form zones of climax vegetation only in certain local areas of Montana. Usually, a belt of climax *Pinus ponderosa* forest separates grassland from climax *Pseudotsuga* forests. When *Pinus ponderosa* is found above this belt, it usually is either a topographic climax on steep southerly slopes or a seral component of stands in other climax series (this relationship is shown in fig. 6). In the southwestern part of the State (fig. 1), *Pinus ponderosa* does not occur and the grasslands give way directly to *Pseudotsuga* forests. The valley base level in these mountain areas usually exceeds 5,500 feet elevation, and apparently the climate is too cold for *Pinus ponderosa*.

Vegetation.--*Pinus ponderosa* and *Juniperus scopulorum* are the only successfully reproducing trees in this series. Although *Pseudotsuga* is found scattered on rocky microsites, there is no indication that it can regenerate effectively or that it will become more abundant at climax.

Pinus ponderosa savannas (grasslands with scattered trees) are found in the eastern part of Montana and to a limited extent in the mountainous western portions. However, our classification includes only sites potentially capable of supporting at least 25 percent coverage by tree canopies. This appears to be an acceptable breakpoint between "savanna" and "open forest" (Penfound 1967).

R. and J. Daubenmire (1968) discussed two groups of *Pinus ponderosa* habitat types; (1) a shrubby group on deep, heavy-textured fertile soils; and (2) a grassy group on stony, coarse-textured, or shallow soils (this includes the *Pinus-Purshia* habitat type in which *Purshia tridentata* is superimposed over the same bunchgrasses). In the mountains of Montana, the grassy group of *Pinus ponderosa* habitats predominates (fig. 10). Stands are fairly open and regeneration is sparse, but rather well distributed. In the eastern part of central Montana and in southeastern Montana, both grassy and shrubby groups are abundant (fig. 11 and 12); tree reproduction in the shrubby group tends to occur in dense patches.

In contrast, in northern Idaho and adjacent Washington, R. and J. Daubenmire (1968) described dense patches of reproduction in the grassy group, and sparse, scattered reproduction in the shrubby group. Interestingly, most of the Daubenmires' grassy stands were on gentle terrain, while the shrubby stands were on steeper slopes. Our west-side Montana stands (grassy) were on steep terrain, and our east-side shrubby stands were on gentler terrain. The few grassy stands we observed on level ground

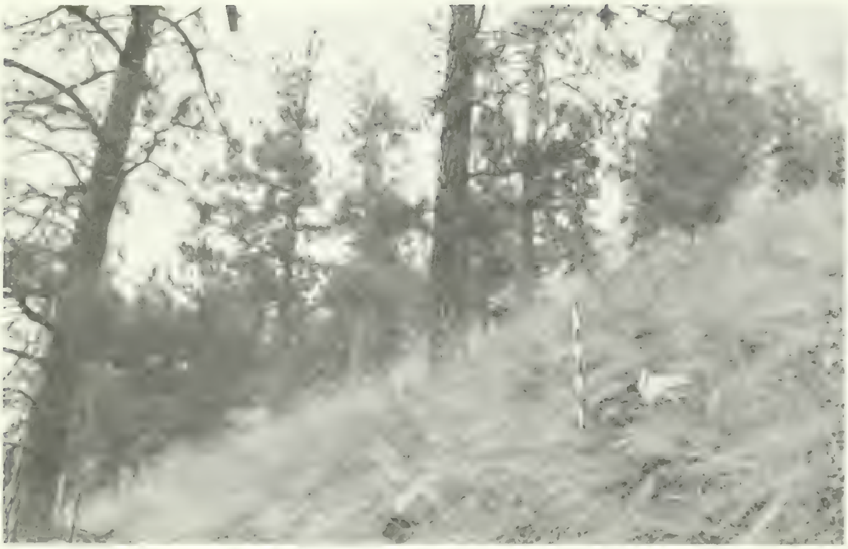


Figure 10.--**Pinus ponderosa/ Agropyron spicatum** *h.t. on a steep southwest exposure (2,750 feet elev.) near Ravalli in northwestern Montana.*

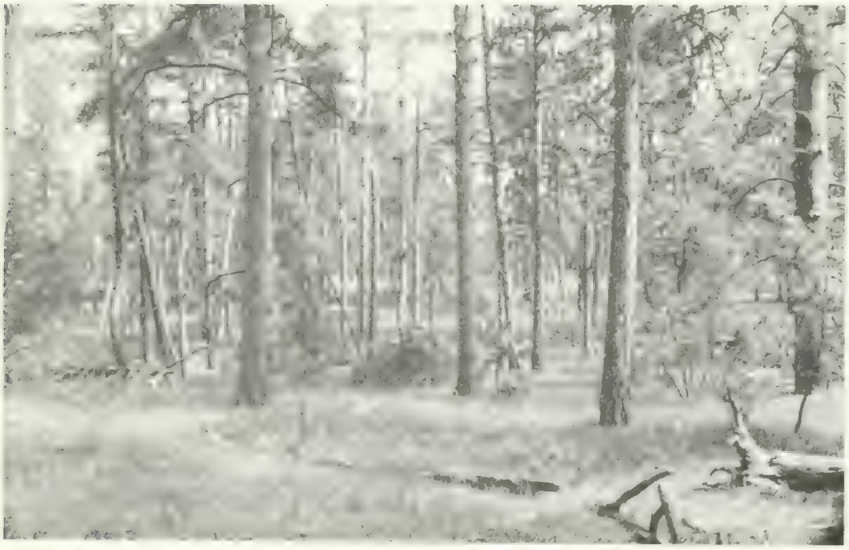


Figure 11.--**Pinus ponderosa/ Festuca idahoensis** *h.t. (***F. idahoensis** *phase) on gentle terrain (4,300 feet elev.) east of Ashland in southeastern Montana.*

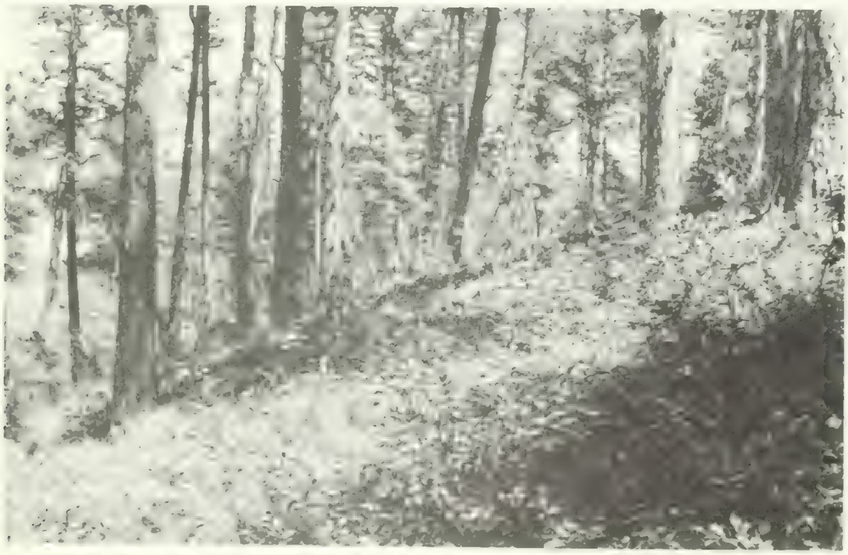


Figure 12.--**Pinus ponderosa/ Prunus virginiana** *h.t. (***P. virginiana** *phase) on a moderate north slope (4,000 feet elev.) east of Ashland in southeastern Montana. The* **Prunus** *has been browsed back by deer.*

in western Montana had dense, patchy reproduction. Thus it appears that topography may influence natural seedbed preparation and hence regeneration.

The shrubby group is poorly developed in the Montana Rockies. If a dense shrubby layer occurs beneath an overstory of *Pinus ponderosa, Pseudotsuga* is usually regenerating and is the indicated climax.

Substantial genetic differences appear to exist between west- and east-side populations of *Pinus ponderosa*. A manifestation of this is the high frequency of trees having mostly two needles per fascicle in the eastern part of central Montana and in southeastern Montana. A much smaller proportion of trees bearing two-needle fascicles occurred in sample plots near Helena, and few if any were found in *Pinus ponderosa* west of the Divide. Height growth differential also suggests east-west genetic differences in this species; trees in eastern Montana may grow as rapidly as their west-side counterparts, but they reach their maximum height at an earlier age (appendix E-2).

East of the Continental Divide *Rhus trilobata* is commonly encountered throughout the *Pinus ponderosa* series. In central and southeastern Montana, the grassy group of *Pinus ponderosa* habitat types includes several additional species. *Yucca glauca*, and *Opuntia* spp., *Carex pensylvanica, Bouteloua* spp., and *Andropogon* spp. are found on some of the driest sites.

Soil.--Soils are variable throughout this series. The surface horizons are gravelly in all types except the *Berberis repens* phase of the *PIPO/SYAL* h.t. Less surface rock and bare soil are exposed in the shrubby group of habitat types, but this may be attributable to heavier duff accumulation and more undergrowth rather than inherent site characteristics.

Fire history.--Before the advent of modern fire suppression, ground fires were frequent in most *Pinus ponderosa* habitat types, but had little effect upon vegetative composition. Of the major undergrowth species, only *Purshia tridentata* is likely to be killed by fire, and it reinvades burned areas quickly (R. and J. Daubenmire 1968). In the tree layer, only saplings and smaller poles are normally killed by most fires in these habitat types.

Productivity/Management.--Timber productivity ranges from very low to moderate within the series (appendix E). The grassy habitat types (including *PIPO/PUTR*) support open forests with stockability limitations and slow growth rates. The bunchgrass-dominated undergrowth has above-average forage potential for livestock or big-game winter range, depending on location within a particular landscape.

The shrubby habitat types support closed-canopy forests with a higher productivity potential (appendix E). Forage production for domestic livestock is lower under the closed canopies, although browse species may provide good forage for big game.

Wellner and Ryker (1973) suggest that a full range of silvicultural systems are available for timber harvesting and regeneration in this series. Under any system, natural regeneration will be slow because good seed crops are infrequent and soil moisture is often inadequate for seedling establishment. Mechanical site preparation will aid establishment by reducing competition for moisture.

Foiles and Curtis (1973), in applying cutting methods to R. and J. Daubenmires' (1968) *Pinus ponderosa* habitat types, emphasize clearcutting and mechanical site preparation where dwarf mistletoe is present or where timber production is the primary goal. We advocate caution in clearcutting in this series in Montana for several reasons:

1. Dwarf mistletoe is rarely found on *Pinus ponderosa* in Montana.

2. Many natural stands, especially in the grassy group, are unevenaged.

3. Timber production often will not be the primary goal because other multiple-use values are often higher.

Based on these considerations, we suggest selection or shelterwood systems coupled with a long natural regeneration period as a general guideline for this series. In practice, stand prescriptions should be based on individual stand conditions, local experience, and management objectives. For instance, even-aged stands in the *PIPO/SYAL* and *PIPO/PRVI* h.t.s. may be suited to seed-tree or clearcut systems.

Pinus ponderosa/Andropogon spp. h.t.
(*PIPO/AND*; ponderosa pine/bluestem)

Distribution.--This is a minor habitat type in southeastern Montana, where it apparently represents the driest conditions within the *Pinus ponderosa* series. It occurs rarely in the vicinity of Ashland (where our one stand was sampled), but is reportedly more common eastward in the Long Pine Mountains near the South Dakota border. Stands are found on south-facing slopes at elevations near 4,000 feet. This habitat type replaces *PIPO/FEID* and *PIPO/AGSP* as one goes eastward toward the Black Hills, where Thilenius (1972) described a similar "habitat unit" (No. 11--*Pinus ponderosa/Andropogon scoparius*).

Vegetation.--Very open stands of *Pinus ponderosa* are typical. Undergrowth is dominated by rather low-growing forms of either *Andropogon gerardii* or *A. scoparius* and dry-site forbs. *Agropyron spicatum* and *Festuca idahoensis* are poorly represented.

Management.--Management implications are similar to those for the *PIPO/AGSP* h.t.

Pinus ponderosa/Agropyron spicatum h.t.
(*PIPO/AGSP*; ponderosa pine/bluebunch wheatgrass)

Distribution.--The *PIPO/AGSP* h.t. is widespread in Montana below 4,800 feet elevation on the driest forested sites, especially on south-facing slopes.

Vegetation.--*Pinus ponderosa*, and occasionally *Juniperus scopulorum*, are the only successful coniferous trees. Grassland forbs and minor amounts of shrubs accompany *Agropyron spicatum* in the undergrowth: these include *Balsamorhiza sagittata, Lithospermum ruderale*, and *Prunus virginiana*. Stands in western Montana have undergrowth composition similar to that of R. and J. Daubenmires' (1968) *Pinus-Agropyron* h.t. However, species composition is somewhat different on some sites east of the Continental Divide (as discussed in the series description), and this may warrant future phase recognition.

Soil/Climate.--Our stands were on a variety of sedimentary parent materials, the majority of which were calcareous (appendix D-1). Surface soils were gravelly loams to gravelly silts and ranged from acidic to slightly basic, depending on the parent material. Ground surfaces had moderate bare soil (7 percent) and little rock exposed (3 percent); duff depth averaged less than 4 cm. Most of the soils had an A1 horizon.

Weather data for Roundup (appendix D-2) reflect the climate of this habitat type in central Montana.

Productivity/Management.--Although forage production is low, winter use by mule deer was evident on most sites. Occasional evidence of elk use was also observed.

This habitat type may have moderate potential for livestock forage production where slopes are not too steep.

Timber productivity is low to very low, with low site indexes and stockability limitations (appendix E). Clearcutting will generally result in conversion to a grassland community with very slow reinvasion of *Pinus ponderosa*. Intensive site preparation and planting may succeed, but the expense is difficult to justify with such low growth potential. Light selection or sanitation-salvage cutting can provide some timber while maintaining site protection. Natural regeneration may take 20 to 40 years, but this should be acceptable under a selection system of management.

Other studies.--A *PIPO/AGSP* h.t. has been described by R. and J. Daubenmire (1968), by McLean (1970) in British Columbia, by Hoffman and Alexander (1976) in Wyoming, and by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) in central Idaho. This type is more variable in Montana than in other areas.

Pinus ponderosa/Festuca idahoensis h.t.
(*PIPO/FEID*; ponderosa pine/Idaho fescue)

Distribution.--The *PIPO/FEID* h.t. occurs throughout Montana wherever the *Pinus ponderosa* climax forest zone exists. It occurs primarily on south- and west-facing slopes with better soil development or in areas less droughty than the *PIPO/AGSP* h.t. Occasionally it is found on benchlands and gentle north slopes near lower timberline adjacent either to *Festuca idahoensis* grasslands or to the *PIPO/AGSP* h.t. on drier exposures. Elevations are less than 5,000 feet.

Vegetation.--*Festuca idahoensis* and/or *Festuca scabrella* are common in the undergrowth. *Agropyron spicatum* is usually present. Associated species are similar to those of the *PIPO/AGSP* h.t., except for greater frequency of *Antennaria rosea* on the *PIPO/FEID* h.t. and of *Danthonia unispicata* on the *PIPO/FEID* h.t., *FEID* phase in the Custer National Forest.

Festuca idahoensis (FEID) phase.--This phase is common in west-central and southeastern Montana. *Festuca idahoensis* is well represented and *Festuca scabrella* is scarce.

Festuca scabrella (FESC) phase.--This phase is frequently found in west-central and central Montana. *Festuca scabrella* is common, reflecting sites that are cooler, less droughty, or having better soil development within the *PIPO/FEID* h.t. Canopy coverage for bunchgrasses averages substantially higher than for the *Festuca idahoensis* phase. Because *Festuca scabrella* decreases markedly in coverage after several years of heavy grazing (Moss and Campbell 1947), its mere presence under such conditions is sufficient evidence for classification in this phase.

Soil.--Our stands were on a variety of parent materials (appendix D-1). Surface soils were gravelly loams to gravelly silts. Most of the soils were acidic, although a few that developed from calcareous parent materials were slightly basic. Ground surfaces had little bare soil and moderate amounts of exposed rock; duff depth averaged 4 cm. Most of the soils have darkened A1 surface horizons, reflecting the forb and grass influence on soil development.

Productivity/Management.--On gentle terrain *PIPO/FEID* is one of the better forest habitat types for production of forage for domestic stock. Forage production is considerably greater than in the *PIPO/AGSP* h.t., especially in the *Festuca scabrella* phase (appendix C-1) Mule deer apparently use these sites as both winter and summer range. Elk winter use appears greater than in the *PIPO/AGSP* h.t., perhaps due to better cover and forage. Forage allocation between big game and domestic stock should be a major management consideration in many areas of this habitat type.

Timber productivity is low, due to both low site index and stockability limitations (appendix E). Silvicultural considerations are similar to those described for the *PIPO/AGSP* h.t.

Other studies.--The *FEID* phase is nearly equivalent to the *Pinus ponderosa/Festuca idahoensis* h.t. described by McLean (1970), Hoffman and Alexander (1976), Steele and others (1975 preliminary draft of forest habitat types of central Idaho, USDA Forest Service, Intermountain Station), and R. and J. Daubenmire (1968). However, *Agropyron spicatum* is apparently more prevalent in Montana than in northern Idaho. The *FESC* phase has not been described elsewhere.

Pinus ponderosa/Purshia tridentata h.t.
(*PIPO/PUTR*; ponderosa pine/bitterbrush)

Distribution.--This habitat type occurs primarily on dry benches and rocky slopes at low elevations. It is locally common in the Kootenai River canyon as well as in the vicinities of Plains, Darby, and Helena.

Vegetation.--In general the undergrowth composition is similar to that of the *PIPO/AGSP* or *PIPO/FEID* h.t. with the addition of *Purshia tridentata*.

Sometimes *Prunus virginiana*, and in the Helena vicinity *Rhus trilobata*, share dominance with *Purshia*. *Cercocarpus ledifolius* is an associate of *Purshia* in stands near Darby, but it is restricted to rock outcrops.

Agropyron spicatum (*AGSP*) phase.--*Agropyron* is the dominant grass, and the site appears drier than in the *Festuca idahoensis* phase. Bare soil is more obvious, bunchgrass canopy coverage averages only 16 percent, and litter is sparse.

Festuca idahoensis (*FEID*) phase.--*Festuca idahoensis*, *F. scabrella*, and *Agropyron spicatum* are the dominant grasses, and the undergrowth is better developed than in the *Agropyron spicatum* phase. Bare soil is less conspicuous, slopes are gentle, and bunchgrasses have a combined average canopy coverage of 50 percent. This phase is more important for both livestock and big game due to the high coverage of bunchgrasses.

Soil/Climate.--About half of the sample stands were on calcareous parent materials (appendix D-1). Surface soils were gravelly, but not more so than other h.t.s in this series. Reactions were acidic to slightly basic, depending on parent material. Ground surfaces had moderate (averages of 4 and 5 percent) exposed rock. The *AGSP* phase had considerable bare soil (17 percent) and less than 1 cm of duff, whereas the *FEID* phase had 6 percent bare soil with duff depth averaging 2.4 cm. All of the soils had darkened A1 surface horizons.

Weather data from Canyon Ferry (appendix D-2) provide an example of the climate on a *PIPO/PUTR* site.

Productivity/Management.--Forage production for domestic stock, deer, and elk is substantial. Deer and elk winter use is heavy because of mild temperatures, lack of snow cover, and the presence of *Purshia tridentata*, one of the more desirable big-game browse species. *Purshia tridentata* is killed by ground fire but apparently reinvades quickly following surface fires (R. and J. Daubenmire 1968).

Timber productivity is very low, because of slow growth and stockability limitations (appendix E). Silvicultural considerations are similar to those described for the *PIPO/AGSP* h.t.

Other studies.--R. and J. Daubenmire (1968) described situations in this habitat type in which *Stipa comata* or *Aristida longiseta* dominated the forb layer. *Stipa* was an important component along with *Agropyron spicatum* near Rexford, Montana, but this situation was not found elsewhere in the State. R. and J. Daubenmire (1968) have cited several examples of this habitat type in the northwestern United States and adjacent British Columbia.

Pinus ponderosa/Symphoricarpos albus h.t.
(*PIPO/SYAL*; ponderosa pine/snowberry)

Distribution.--This habitat type is common on benchlands and north-facing slopes in central and southeastern Montana. It is occasionally found in western Montana on benchlands in the lower-elevation valleys. Sometimes the dry extreme of *PIPO/SYAL* develops on south-facing slopes, but the bunchgrass-dominated *Pinus ponderosa* habitat types are generally more prevalent on such exposures. West of the Continental Divide *PIPO/SYAL* is often absent, since the grassy *Pinus ponderosa* habitat types usually are bordered by the *Pseudotsuga* series, often the *PSME/SYAL* h.t. Elevations of sample plots ranged from 2,600 feet at Plains to 5,400 feet near Lewistown.

Vegetation.--Some stands appear even-aged, exhibiting a relatively uniform, closed canopy. Other stands have several age classes, reflecting the influence of ground fires. Because of fairly dense shade and heavy duff accumulation, disturbance appears necessary to establish regeneration. Undergrowth is dominated by *Symphoricarpos albus* and other shrubs, accompanied by a rich assortment of perennial forbs and grasses.

Symphoricarpos albus (SYAL) phase/Soil.--This is the most widespread phase. Bunchgrasses are often codominant with *Symphoricarpos;* such stands either are seral, or are transitional to the grassy *Pinus ponderosa* habitat types.

Parent materials in this phase were variable with only one stand found on calcareous parent material (appendix D-1). Surface soils were slightly acidic and gravelly with a full range of textures from loamy sands to silty clay loams. Ground surfaces were rock-free with little bare mineral soil exposed in natural stands; duff depth averaged 4.5 cm. Although most soils had darkened A1 horizons, a few displayed surface A2 or B horizons.

Soil moisture depletion during the growing season has been documented for this phase in two different studies (Daubenmire 1968a, McMinn 1952). Soil dries to the wilting point in the surface horizons during late June to July. By mid- to late August the wilting point depth reaches at least 20 inches.

Berberis repens (BERE) phase/Soil.--This minor phase was found only in central Montana in the vicinity of Lewistown and Roundup where it occupies gentle slopes and benches more moist than those occupied by the *SYAL* phase. *Berberis repens* is common in the luxuriant undergrowth, and bunchgrasses are poorly represented. *Juniperus communis* and *Spiraea betulifolia* are common in the shrub layer. *Schizachne purpurascens* is often present, indicating some similarity to the *PIPO/PRVI* h.t.

Parent materials in this phase were exclusively limestone (appendix D-1). Soils were virtually gravel-free in the surface 20 cm and ranged from slightly acidic to slightly basic. Textures ranged from silt loam to silty clay loam. Ground surfaces were rock-free and no bare soil was exposed in natural stands. Average duff accumulation was greater than 5 cm. All soils had well-developed A1 surface horizons.

Climate.--Weather data for Lewistown represent the climate of the *PIPO/SYAL* h.t. in central Montana (appendix D-2).

Productivity/Management.--Timber productivity is low, although it is one of the more productive habitat types in the *Pinus ponderosa* series (appendix E). In western Montana, site index for *Pinus ponderosa* is similar to that for the grassy habitat types, but basal areas in *PIPO/SYAL* are substantially greater, indicating higher stockability and volume potentials. Eastward, both site indexes and basal areas are generally higher than for the grassy habitat types in this series. *PIPO/SYAL* stands should regenerate faster than the grassy habitat types, if site preparation is adequate. However, clearcuts may be difficult to regenerate due to droughtiness and competition from seral bunchgrasses.

Forage production is somewhat variable. Bunchgrasses are well represented in the *Symphoricarpos albus* phase (appendix C-1), indicating a good potential for domestic livestock. This potential declines in later successional stages. Both phases have a fair complement of palatable big-game browse species.

Other studies.--The *SYAL* phase is comparable to the *Pinus ponderosa/Symphoricarpos albus* h.t. described by R. & J. Daubenmire (1968) and Robert Steele and others (1975, preliminary draft of forest habitat types of central Idaho, USDA Forest Service, Intermountain Station). Hoffman and Alexander (1976) describe a *Pinus ponderosa/Spiraea betulifolia* h.t. in Wyoming that is similar to our *BERE* phase.

Pinus ponderosa/Prunus virginiana h.t.
(*PIPO/PRVI*; ponderosa pine/chokecherry)

Distribution.--This habitat type was found only in southeastern Montana where it is restricted to moist, north-facing slopes and draws mostly between 3,900 and 4,400 feet in elevation.

Vegetation.--Stand structure is variable. Some stands appear to be all-aged, with scattered regeneration and rather uniform representation of size classes. Other stands show two or even three distinct size classes.

Undergrowth differs from other *Pinus ponderosa* habitat types. *Prunus virginiana, Amelanchier alnifolia,* and *Symphoricarpos albus* form a shrubby layer. Green ash, *Fraxinus pennsylvanica*, occurs on semiriparian sites. *Berberis repens, Arnica cordifolia, Cystopteris fragilis, Rhus radicans, Galium boreale, Schizachne purpurascens* and *Agrostis scabra* are characteristic of this habitat type.

Prunus virginiana (PRVI) phase.--This is the common phase of the habitat type.

Shepherdia canadensis (SHCA) phase.--This minor phase was found only on the northern Cheyenne Indian Reservation west of Ashland. It is distinguished by a shrub layer dominated by *Shepherdia canadensis*. In addition, *Arctostaphylos uva-ursi, Pyrola* spp., *Spiraea betulifolia* and occasionally *Linnaea borealis* help to differentiate this phase from the rest of the *PIPO/PRVI* h.t.

Soil/Climate.--This habitat type was found only on noncalcareous sandstone, siltstone, and shale parent materials (appendix D-1). Surface soils were acidic to slightly acidic gravelly silt loams with well-developed A1 horizons. Ground surfaces were virtually rock-free and no mineral soil was exposed in natural stands. Duff depths averaged 5.8 cm in the *PRVI* phase and 3.5 cm in the *SHCA* phase.

Although annual precipitation is low in this region (about 11 inches at Ashland), much of it falls during the growing season. It is doubtful if severe periods of summer drought occur on these sites.

Productivity/Management.--Timber productivity is low to moderate (appendix E). Average site index and maximum stand heights are higher than other eastside *Pinus ponderosa* habitat types.

A rich assortment of palatable shrubs and forbs makes this a preferred wildlife habitat type. Mule deer browse heavily on *Prunus virginiana, Amelanchier alnifolia,* and other shrubs, often severely restricting development of the shrubs.

Cattle make little use of this habitat type, preferring adjacent open forests with bunchgrass undergrowth.

Other studies.--Thilenius (1972) described three habitat units in the Black Hills that appear similar to the *PRVI* phase: *Pinus ponderosa-Quercus macrocarpa/*

Prunus virginiana/Symphoricarpos albus/Berberis repens (HU-6), *Pinus ponderosa-Quercus macrocarpa/Prunus virginiana/Symphoricarpos albus/Schizachne purpurascens-Carex foena* (HU-7), and part of *Pinus ponderosa/Prunus virginiana/Amelanchier alnifolia/Galium biflorum* (HU-8). The *SHCA* phase appears to be related to two of Thilenius' (1972) habitat units: *Pinus ponderosa/Shepherdia canadensis/Symphoricarpos albus/Arctostaphylos uva-ursi* (HU-2) and part of *Pinus ponderosa/Prunus virginiana/Amelanchier alnifolia/Galium biflorum* (HU-8).

Pseudotsuga menziesii Series

Distribution.--*Pseudotsuga* is the indicated climax in a broad forest belt at moderate elevations in the Montana Rockies. Unlike the drier *Pinus ponderosa* and *Pinus flexilis* series, the *Pseudotsuga* series does not extend appreciably out onto the Great Plains. It is associated with well-drained mountain slopes and valleys and extends from the lower elevations of forest growth up to about 5,500 feet on southern exposures in northwestern Montana, and from lower timberline up to about 7,500 feet on warm aspects in southern Montana.

This climax series is broader and more diverse in the Montana Rockies than in northern Idaho. In fact, the *Pseudotsuga* and *Abies lasiocarpa* series form the bulk of the coniferous forest in the Montana Rockies.

The *Pseudotsuga* series is bordered on warmer, drier sites by the *Pinus ponderosa* or *P. flexilis* series or by grassland. In many areas it is bounded on more moist sites by the *Picea* series, and in northwestern Montana often by the *Abies grandis* series. At higher elevations it gives way to the *Abies lasiocarpa* series.

Vegetation.-- *Pseudotsuga menziesii* is more shade-tolerant than its principal associates, which are *Pinus ponderosa* on warm-dry sites within the series, and *Pinus contorta* and (west of the Continental Divide) *Larix occidentalis* under cool-moist conditions. Historically, wildfire has helped maintain these seral species in much of the *Pseudotsuga* series. All four of these species are adapted to fire, and they regenerate well following disturbance. *Pinus ponderosa* and *Larix occidentalis* commonly survive 300 to 400 years, while *Pinus contorta* survives only about half as long. In the absence of disturbance *Pseudotsuga* is the only species that continues to regenerate in any abundance; thus it gradually becomes dominant in undisturbed stands.

Undergrowth is variable among the 15 habitat types in this series. Bunchgrasses dominate three of the driest habitat types: *Pseudotsuga/Agropyron spicatum*, *Pseudotsuga/Festuca idahoensis*, and *Pseudotsuga/Festuca scabrella*. These often appear similar to the corresponding *Pinus ponderosa*/bunchgrass habitat types (fig. 13). In some of the other *Pseudotsuga* habitat types (for example, *PSME/CARU*), bunchgrasses often occur under seral conditions and may persist in openings. Several of the cooler *Pseudotsuga* habitat types (e.g., *PSME/VACA*, *PSME/LIBO*, *PSME/VAGL*) have undergrowth roughly comparable to some types in the *Abies lasiocarpa* series (fig. 14).

Soil/Climate.--Soils are variable throughout the series. In general, habitat types were not strongly related to specific parent materials, although many were found only on noncalcareous substrates. Surface soils are consistently gravelly and acidic, except on calcareous substrates. Surface rock and bare soil are conspicuous in the *Pseudotsuga*/bunchgrass h.t.s and average duff depth is less than 3 cm. Average duff depth in the other *Pseudotsuga* habitat types is from 3 to 6 cm.

Some climatic parameters for the *Pseudotsuga* series are shown in appendix D-2.

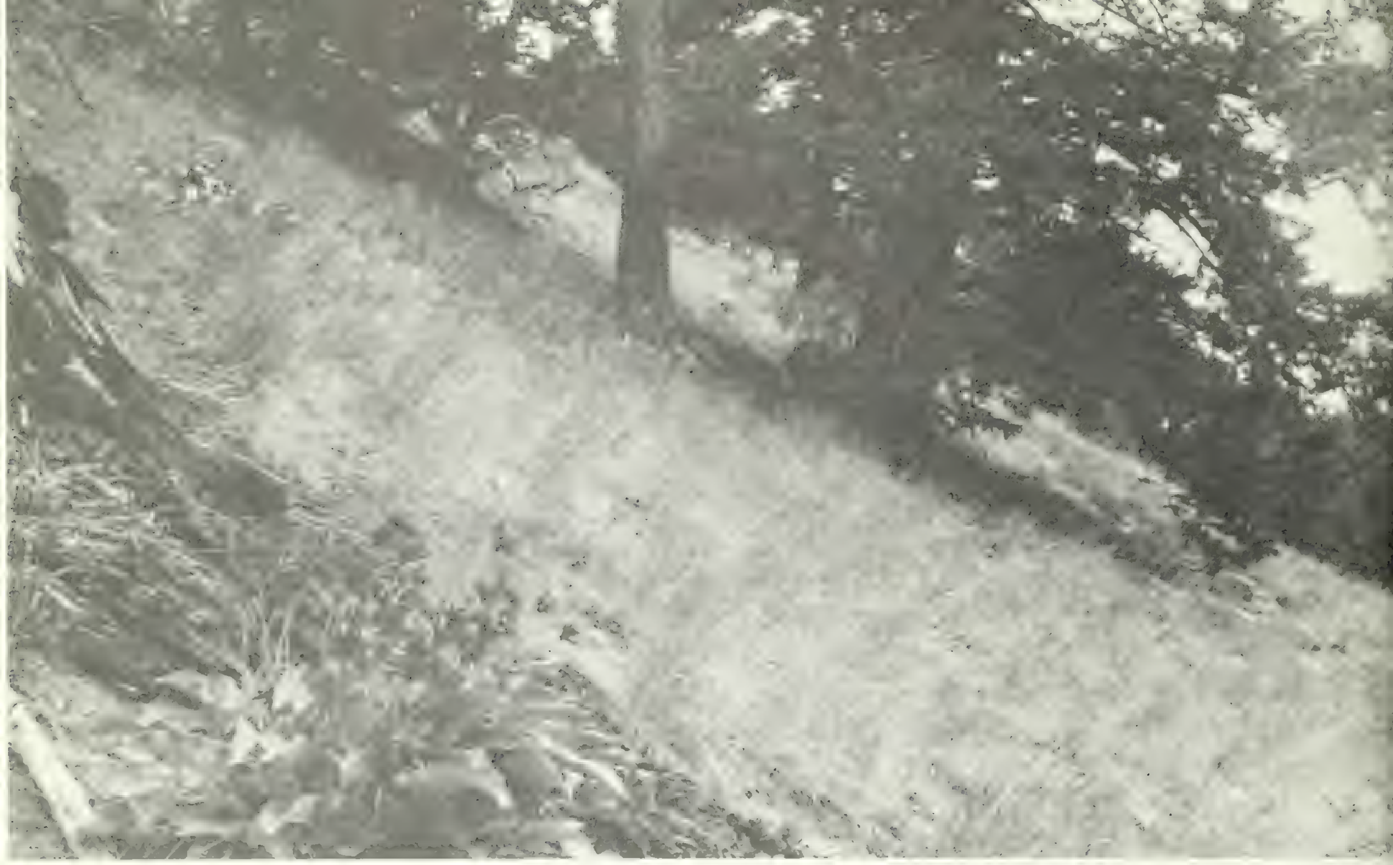


Figure 13.--Pseudotsuga menziesii/Agropyron spicatum *h.t. on a steep south slope (5,650 feet elev.) east of Philipsburg in west-central Montana. Soil is loose and sandy; much of the ground surface is exposed, partially because of grazing.*

Figure 14.--Pseudotsuga menziesii/Vaccinium globulare *h.t.* (Arctostaphylos uva-ursi *phase) on a south exposure (4,700 feet elev.) in a relatively moist area west of Missoula in west-central Montana. Seral* Pinus ponderosa *dominates in the overstory;* Vaccinium *and* Xerophyllum *can be seen in the undergrowth.*

Fire history.--Wildfire appears to have occurred more frequently in this series than in cooler or more moist series. However, fires have generally been less destructive to mature stands in this series than in the cooler or more moist series (Wellner 1970; Arno 1976). Natural fire frequency in many stands has been between 10 and 30 years.

Productivity/Management.--Timber productivity ranges primarily from low to moderate in this series (appendix E). Production of forage for domestic stock and big game varies considerably between habitat types. Lower elevations and southerly exposures are often important for deer and elk winter range.

Pseudotsuga menziesii/Agropyron spicatum h.t.
(*PSME/AGSP*; Douglas-fir/bluebunch wheatgrass)

Distribution.--The *PSME/AGSP* h.t. represents the warm-dry extreme of the *Pseudotsuga* climax series. It occurs mostly on steep southern or western exposures, and is most common in central and west-central Montana. Elevation of sample plots ranged from 5,000 to 6,500 feet. It has a cooler environment and shorter growing season than the *PIPO/AGSP* h.t.

Vegetation.--Trees are widely spaced and stand structure is similar to that of the grassy group of habitat types in the *Pinus ponderosa* series. *Pinus ponderosa* is often a major seral or climax associate. On limestone-derived soils, *Pinus flexilis* is commonly present as a minor seral component.

Undergrowth is dominated by *Agropyron spicatum* and *Balsamorhiza sagittata*. Scattered shrubs may be present with low coverages (appendix C). Undergrowth composition is quite similar to the *PIPO/AGSP* h.t.; however, the *PSME/AGSP* h.t. has no appreciable representation of Great Plains grassland species. *Festuca idahoensis* was common in a few *PSME/AGSP* stands west of the Continental Divide, but *Pinus ponderosa* was a major seral species and site features fit the *PSME/AGSP* description.

Soil.--Our stands were on a variety of calcareous and noncalcareous parent materials (appendix D-1). Surface soils were gravelly (42 percent), acidic to slightly basic (on limestone), and ranged in texture from loamy sand to silt. Ground surfaces averaged 11 percent rock, 13 percent bare soil, and only 2.5 cm duff depth. All of the soils had an A1 surface horizon.

Productivity/Management.--Forage production for livestock is moderate, but steep slopes limit grazing. Mule deer and elk use was quite evident, apparently as part of their winter range. Browse production is low, but warm exposures encourage frequent use.

Timber productivity is low to very low, as indicated by both low site indexes and stockability limitations (appendix E). Clearcutting in this type will generally result in conversion to grassland with very slow reinvasion of trees. Light selection or sanitation-salvage cutting will permit timber harvest and protect the site. Natural regeneration may take 20 to 40 years, but this should be acceptable under a selection system of management. Intensive cultural work is difficult to justify with such low productivity potential.

Other studies.--McLean (1970) described a very similar *Pseudotsuga/Agropyron* h.t. in British Columbia. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) also describe a comparable situation in central Idaho.

Pseudotsuga menziesii/Festuca idahoensis h.t.
(*PSME/FEID*; Douglas-fir/Idaho fescue)

Distribution.--The *PSME/FEID* h.t. is found on dry sites that are generally cooler than those of the *PSME/AGSP* h.t. It occurs on a variety of aspects usually between 5,600 and 7,350 feet elevation. *PSME/FEID* is common in west-central Montana on the Deerlodge National Forest and in southwestern Montana, but is rare elsewhere. In southwestern Montana it often occurs as a topographic climax at the lower edge of the forest on north slopes. It also forms a topographic climax on southerly exposures at higher elevations. There stands are more open and undergrowth is better developed.

Vegetation.--*PSME/FEID* differs from the other *Pseudotsuga*/bunchgrass habitat types in that *Pinus ponderosa* is essentially absent. *PSME/FEID* occurs in areas where even the valley base elevations are near the upper elevational or cold limits of *P. ponderosa*. Small amounts of *Pinus flexilis* may occur in stands on limestone-derived soils.

As with *PSME/AGSP*, undergrowth coverage is sparse. Common associates of *Festuca idahoensis* include *Ribes cereum*, *Artemisia tridentata*, and *Agropyron spicatum*.

Soil.--Our stands were on a variety of calcareous and noncalcareous parent materials (appendix D-1). Surface soils were acidic, averaged 31 percent gravel content, and ranged in texture from sandy loam to silt. Ground surfaces averaged 9 percent rock, 9 percent bare soil, and 2.4 cm duff depth. Almost all of the soils had an A1 horizon.

Productivity/Management.--Forage potential for livestock is moderate in cleared or open stands. Slopes are often gentle enough to allow domestic livestock grazing. Mule deer and elk use was quite evident, apparently for winter cover and forage.

Timber productivity is low, as reflected by low site-index values and apparent stockability limitations (appendix E). Dense stands on north or east aspects often become stagnated. *Pseudotsuga* is the only commercial tree species in this habitat type. Timber management considerations are similar to those described for the *PSME/AGSP* h.t., except that small clearcuts may be appropriate for stagnated stands on north slopes.

Other studies.--This habitat type has been described for central Idaho (Robert Steele and others 1975 preliminary draft, USDA Forest Service, Intermountain Station). McLean (1970) described a *PSME/FEID* h.t. in British Columbia; however, his description corresponds to our *PSME/CARU* h.t., *AGSP* phase in Montana.

Pseudotsuga menziesii/Festuca scabrella h.t.
(*PSME/FESC*; Douglas-fir/rough fescue)

Distribution.--The *PSME/FESC* h.t. was found only in northwestern, west-central, and central Montana. Most sample stands were on south- or west-facing slopes between 2,700 and 5,700 feet in elevation, but they ranged as high as 7,400 feet in central Montana.

Vegetation.--*Pinus ponderosa* is often a major seral or climax associate with *Pseudotsuga*. Only occasionally are sites found at elevations above the cold limits of *Pinus ponderosa*. *Pinus flexilis* is a minor component of some stands on calcareous soils.

Undergrowth appears similar to that of adjacent *Festuca scabrella* grasslands. Small amounts of *Amelanchier alnifolia*, *Prunus virginiana*, and *Rosa woodsii* are often found. *Purshia tridentata* was abundant in two sample stands; in this situation wildlife management implications might parallel those for the *PIPO/PUTR* h.t. Major grasses and forbs associated with *Festuca scabrella* include *Agropyron spicatum, Festuca idahoensis, Koeleria cristata, Balsamorhiza sagittata,* and *Lithospermum ruderale.*

The *Festuca scabrella* union was given habitat type status in the *Pseudotsuga* series for two reasons: (1) There is a geographical segregation of *PSME/FEID* and *PSME/FESC* h.t.s, the latter occurring to the north; (2) *Pinus ponderosa* is often a major climax associate in the *PSME/FESC* h.t., but is absent in *PSME/FEID. Festuca scabrella* and *F. idahoensis* unions have less-contrasting habitats in the *Pinus flexilis* and *P. ponderosa* series, thus they are classified as phases.

Soil.--Our stands were on a variety of calcareous and noncalcareous parent materials (appendix D-1). Surface soils were acidic, averaged 37 percent gravel content and ranged in texture from loam to silt. Ground surfaces averaged 5 percent rock, 7 percent bare soil, and 2.5 cm duff depth. Many of the soils had an A1 horizon.

Productivity/Management.--On gentle terrain, the *PSME/FESC* h.t. is one of the better forest habitat types for production of forage for domestic stock. Canopy coverage of bunchgrasses is much greater than for other *Pseudotsuga* habitat types (appendix C-1). Mule deer and elk use was quite evident, apparently as winter range.

Timber productivity is low to very low, due to both low site index values and stockability limitations (appendix E). Timber management considerations are similar to those described for the *PSME/AGSP* h.t.

Other studies.--The *PSME/FESC* h.t. has not been described elsewhere.

(*Pseudotsuga menziesii/Vaccinium caespitosum* h.t.
(*PSME/VACA*; Douglas-fir/dwarf huckleberry)

Distribution.--The *PSME/VACA* h.t. is found on relatively warm and moist, but well-drained benches and gentle slopes. It is common in northwestern, west-central, and central Montana. Elevations are mostly 2,500 to 3,800 feet in northwestern Montana, 2,900 to 4,500 feet in west-central Montana, and 5,200 to 6,400 feet east of the Continental Divide. Afternoon temperatures may be high in summer, but in many of these sites cold air accumulation creates a "frost pocket."

Vegetation.--Most stands in northwestern Montana are dominated either by *Pinus ponderosa* or *Larix occidentalis* (fig. 15). East of the Continental Divide and on colder sites in northwestern Montana, *Pinus contorta* is the dominant seral tree species.

Undergrowth is a low, dense layer of *Calamagrostis rubescens, Carex geyeri, Vaccinium caespitosum,* and *Arctostaphylos uva-ursi. Linnaea borealis* is well represented in about a third of the stands sampled, apparently on the more moist sites. *Symphoricarpos albus* is sometimes well represented, but usually has less coverage than *Calamagrostis* and its low-growing associates. *Xerophyllum tenax* is occasionally present on sites in cool mountain canyons.

The open, park-like conditions and large fire-scarred seral trees found in undisturbed stands of *PSME/VACA* suggest a history of frequent ground fires. In many cases *Pseudotsuga* has only recently begun to regenerate, because of past fires or perhaps due to moisture depletion in the surface soil caused by heavy stocking of old-growth *Pinus ponderosa* and *Larix occidentalis* and the dense mat of undergrowth.

Soil/Climate.--Our stands were on a variety of noncalcareous parent materials (appendix D-1). Surface soils were acidic, gravelly (26 percent) sandy loams to loams. Very little rock and bare soil were exposed; duff depth averaged 4.3 cm.

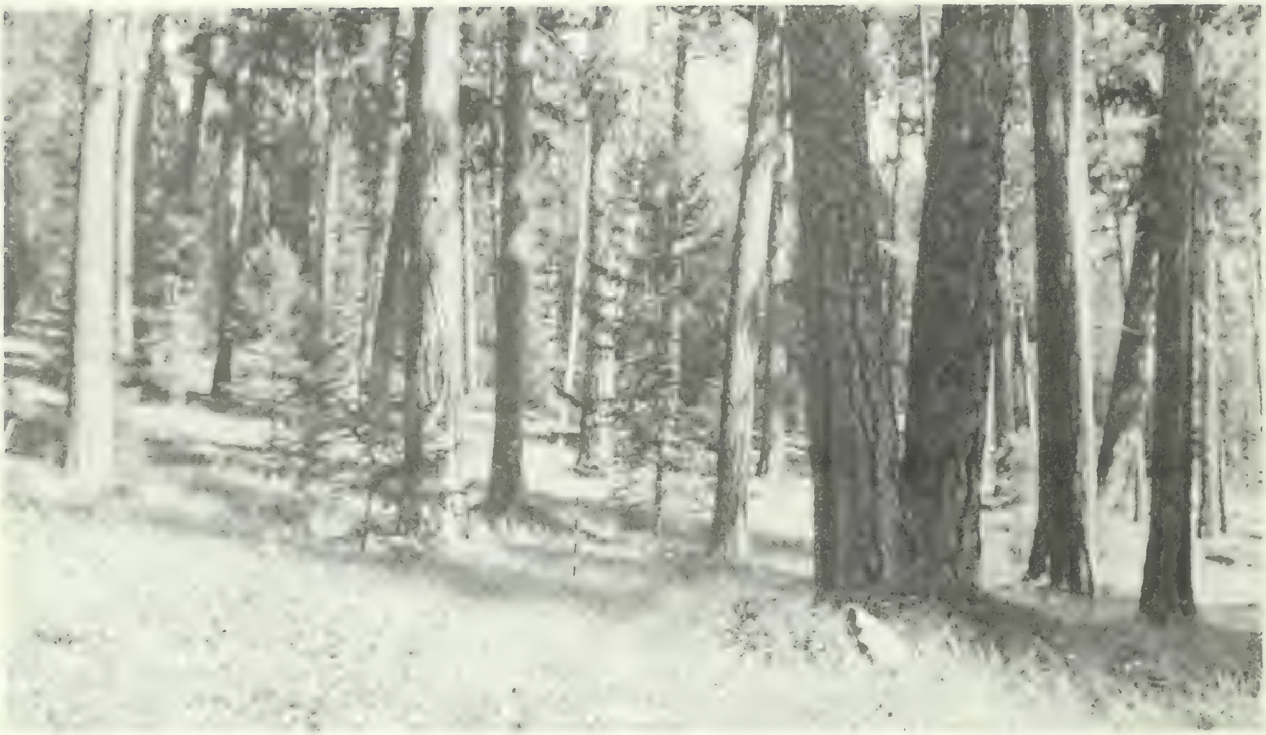


*Figure 15.--*Pseudotsuga menziesii/Vaccinium caespitosum *h.t. on gentle terrain (4,500 feet elev.) northeast of Missoula.* Pinus ponderosa *and* Larix occidentalis *dominate the overstory, but the regeneration is* Pseudotsuga.

Weather data from Greenough and Pleasant Valley (appendix D-2) represent the climate of the *PSME/VACA* h.t. west of the Continental Divide.

Productivity/Management.--West of the Continental Divide this habitat type affords good growth for a mixture of commercially valuable tree species; growth of *Pinus ponderosa* is excellent. Productivity ranges from moderate to high in western Montana (appendix E). Eastward, the habitat type is less productive, *Pinus contorta* is the dominant seral species, and *Pinus ponderosa* and *Larix occidentalis* are absent.

Either even-aged management or selective removal of *Pseudotsuga* will favor perpetuation of seral tree species in this habitat type. Overstory removal will lead to increasing dominance by *Pseudotsuga*. The sod formed by *Calamagrostis rubescens* and its associates may need breaking for successful regeneration of conifers. Wide latitude can be taken in managing these productive and accessible sites.

Domestic stock use was observed only locally. The forage potential for livestock is low in natural stands. However, deer, elk, and occasionally moose use them heavily in winter, if snow depths are not too great.

This habitat type is frequently used for recreation sites, including campgrounds and summer home developments.

Other studies.--Steele and others (1976 preliminary draft, USDA Forest Service, Intermountain Station) has recorded this habitat type in north-central Idaho. In Alberta, that part of Ogilvie's (1962) *Pseudotsuga/Calamagrostis* h.t. which includes *Vaccinium caespitosum* appears to be similar.

Pseudotsuga menziesii/Physocarpus malvaceus h.t.
(*PSME/PHMA*; Douglas-fir/ninebark)

Distribution.--In most of Montana, the *PSME/PHMA* h.t. occurs predominantly on cool and moist north- or east-facing slopes. However, the *Calamagrostis rubescens* phase is usually associated with southerly exposures, and in moist areas of northwestern Montana the *Physocarpus* phase occurs on south-facing slopes. In northwestern and west-central Montana the habitat type was found at elevations of 2,000 to 5,700 feet, in central Montana at 4,800 to 5,800 feet, and in south-central Montana at 5,100 to 6,700 feet.

Vegetation.--The overstory is normally dominated by *Pseudotsuga*. West of the Continental Divide, *Pinus ponderosa, Larix occidentalis,* and *Pinus contorta* are minor seral components of many stands; however, *Pseudotsuga* is usually the dominant tree species in all stages of succession. East of the Continental Divide, *Pseudotsuga* is the only tree species present in appreciable amounts. An exception was found on limestone substrates in south-central Montana, where *Pinus flexilis* was a major associate of *Pseudotsuga* under seral conditions.

Physocarpus malvaceus (PHMA) phase.--*Physocarpus malvaceus* or *Holodiscus discolor* form a dense shrubby layer that dominates the undergrowth (fig. 16). *Symphoricarpos albus, Spiraea betulifolia, Calamagrostis rubescens, Arnica cordifolia,* and *Carex geyeri* are often well represented. *Disporum trachycarpum, Smilacina* spp., *Thalictrum occidentale,* and other moist-site forbs are common. Stands are normally on north or east aspects.

Calamagrostis rubescens (CARU) phase.--This warm-exposure variation of the *PSME/PHMA* h.t. is common in west-central Montana. In mature stands *Calamagrostis rubescens* and *Carex geyeri* are dominant beneath a scattered *Physocarpus* shrub layer. *Agropyron spicatum* and *Balsamorhiza sagittata* are common in half of the sample stands (fig. 17) and they may dominate stands in early seral condition. *Pinus ponderosa* is a major seral dominant on these sites, and *Pinus contorta* and *Larix occidentalis* are absent because of droughty conditions. This phase evidently represents a transition from *PSME/PHMA* to the *PSME/CARU* or *PSME/AGSP* h.t.s.

Soil.--Our stands were on a variety of noncalcareous parent materials west of the Continental Divide; near and east of the Continental Divide stands were also found on limestone (appendix D-1). Surface soils were acidic (slightly basic on limestone), gravelly (average 42 percent), and ranged in texture from sandy loam to silt. Little exposed rock was evident in the *PHMA* phase with about 5 percent in the *CARU* phase. No bare soil was exposed in either phase and duff depth averaged about 4 cm in both.

Productivity/Management.--Timber productivity is moderate to high in western Montana, but only low to moderate eastward (appendix E). The highest productivities are found in western Montana in the *PHMA* phase. East of the Continental Divide, silvicultural prescriptions consider only *Pseudotsuga* since *Pinus ponderosa* and *P. contorta* are rarely present. West of the Divide, *P. ponderosa, P. contorta,* and *Larix occidentalis* may be perpetuated where they occur naturally through even-aged management. Partial cutting favors *Pseudotsuga*, but timber production may be severely reduced in dwarf-mistletoe (*Arceuthobium*) infected stands.

Livestock usually graze only small areas of gentle topography in this type. Heavy grazing can establish a *Poa* disclimax similar to that described by R. and J. Daubenmire (1968).

Big game use of *PSME/PHMA* h.t. is variable, ranging from transitory or bedding activity to heavy winter use by elk and deer. Intensity of use may depend on

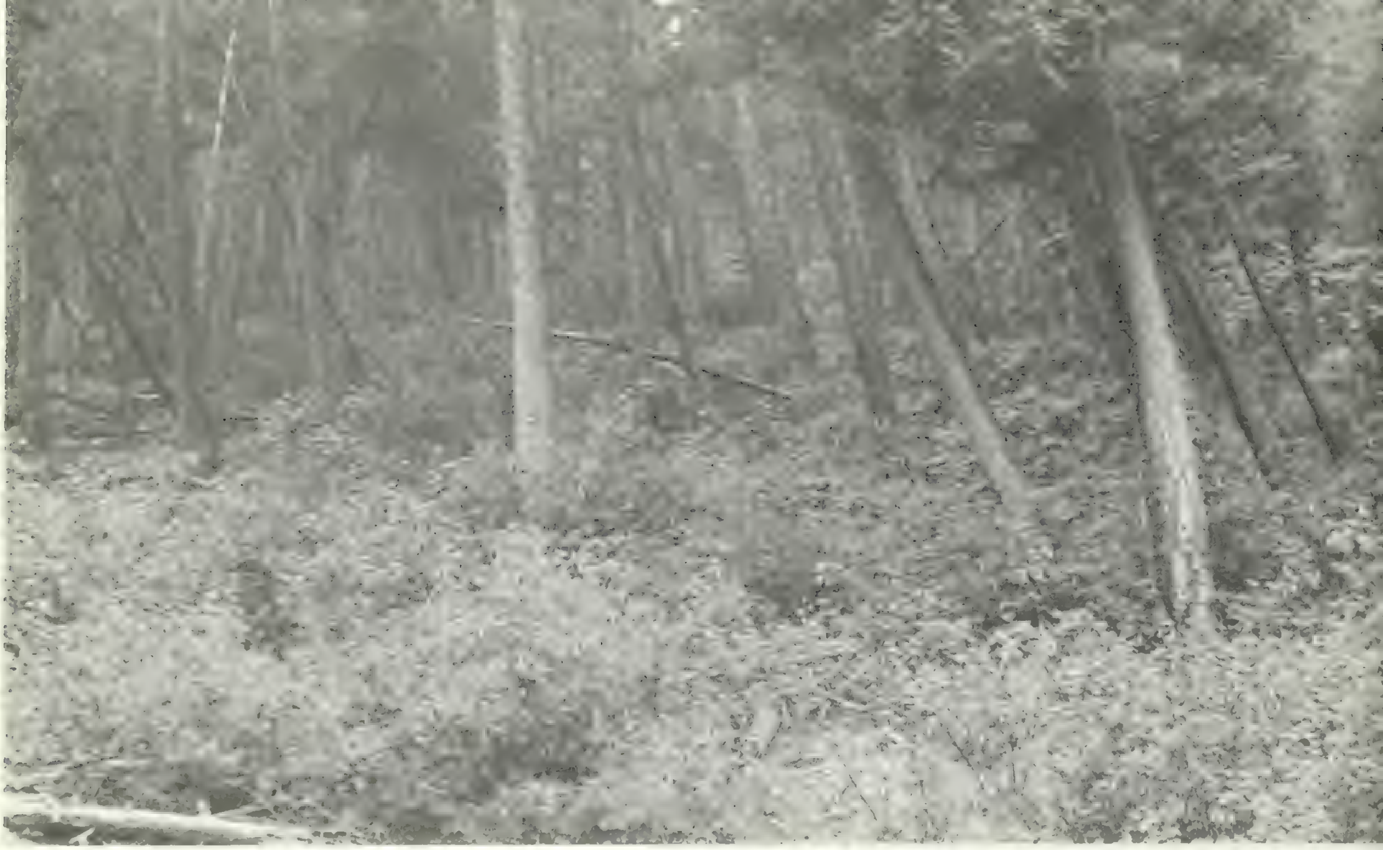
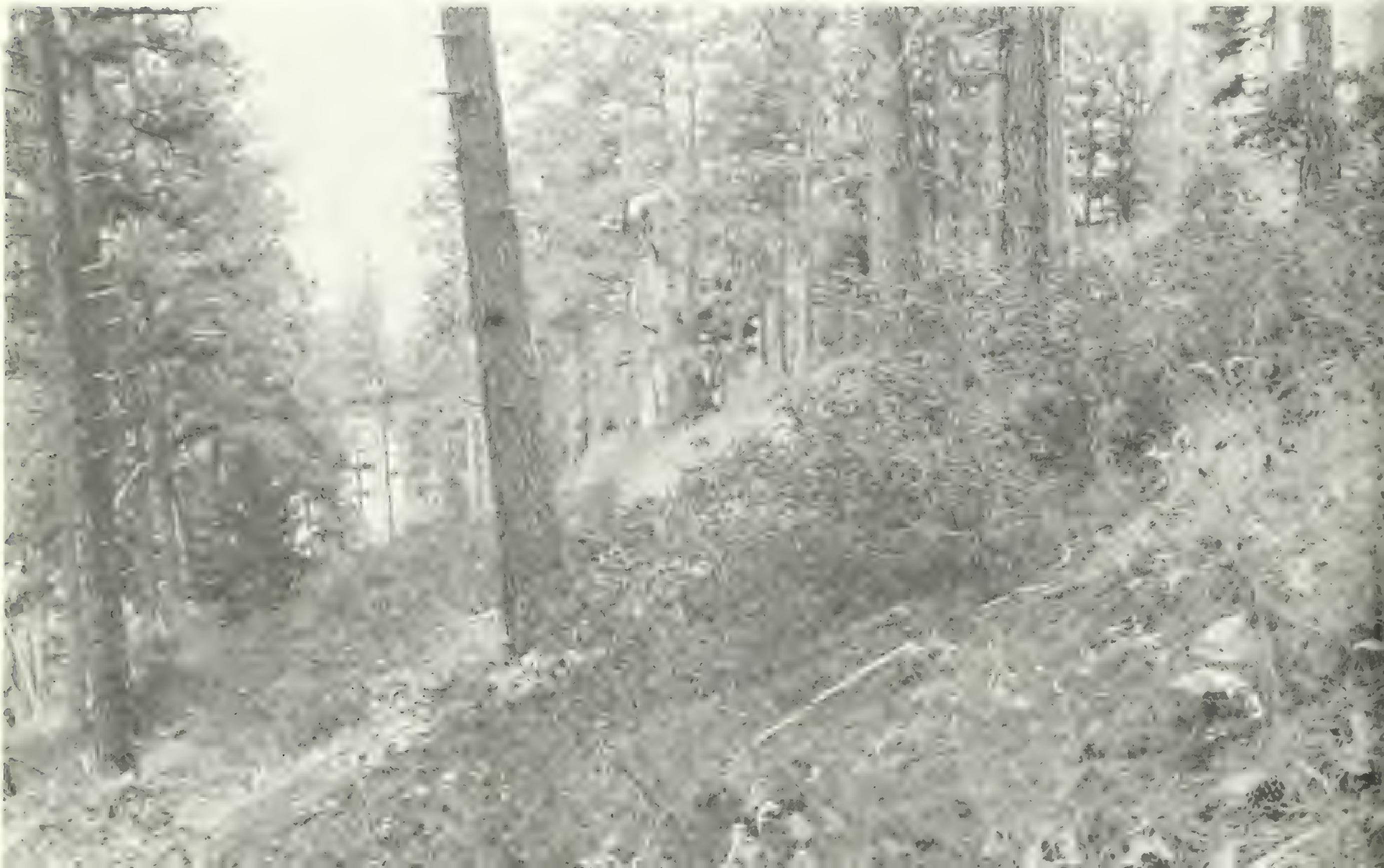


*Figure 16.--*Physocarpus *phase (*PSME/PHMA *h.t.) on a steep east exposure (5,000 feet elev.) south of Drummond in west-central Montana. The overstory is almost purely* Pseudotsuga *about 170 years of age.*

*Figure 17.--*Calamagrostis *phase (*PSME/PHMA *h.t.) on a steep southwest exposure (4,500 feet elev.) southeast of Missoula.* Pinus ponderosa *is a long-lived seral dominant.*



snowpack depth, successional stage, and the availability of favored browse species. The *Calamagrostis rubescens* phase, which occurs on warmer slopes, may have the greatest importance as winter range.

Other studies.--R. and J. Daubenmire (1968) and Hoffman and Alexander (1976) defined *Pseudotsuga/Physocarpus* h.t.s that are similar to our *PSME/PHMA* h.t., *PHMA* phase. Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) reported finding both phases of the habitat type in central Idaho.

Pseudotsuga menziesii/Vaccinium globulare h.t.
(PSME/VAGL; Douglas-fir/blue huckleberry)

Distribution.--*PSME/VAGL* is found on relatively cold sites within the *Pseudotsuga* series, and generally is bordered upslope by the *Abies lasiocarpa* series (*ABLA/XETE* h.t., *VAGL* phase or *ABLA/VAGL* h.t.). It is a major habitat type in vicinities of the Lolo and Bitterroot National Forests and is also prominent in central Montana. It occurs on well-drained slopes at elevations between 4,300 and 6,800 feet.

Vegetation.--*Pseudotsuga* is the indicated climax as well as a vigorous member of most seral communities. *Pinus contorta, Larix occidentalis,* and *Pinus ponderosa* are seral components whose abundance varies considerably by phase. *Vaccinium globulare* is well represented in undergrowth throughout the habitat type. Most stands have a mat of *Calamagrostis rubescens* and *Carex geyeri. Spiraea betulifolia* is usually common, as is *Xerophyllum* in two of the phases.

Arctostaphylos uva-ursi (ARUV) phase.--This phase occurs on relatively warm sites, on moderate southerly slopes mostly between 4,300 and 5,600 feet. It occurs rather extensively near and west of Missoula, as well as along the west side of the Bitterroot Valley. Unlike other phases, *Pinus ponderosa* is a dominant in seral communities, and *Pinus contorta* and *Larix occidentalis* have only minor representation in most stands. *Arctostaphylos uva-ursi* is common in the undergrowth, and *Carex geyeri* and *Xerophyllum* are usually common also. Vegetative composition of stands in this phase is related to that of the *PSME/CARU* h.t., *ARUV* phase, except for the *Vaccinium globulare* and *Xerophyllum*, which are indicative of colder climatic conditions.

Xerophyllum tenax (XETE) phase.--Although this phase is found in the same geographic area as the *ARUV* phase, it occupies cooler sites. It is also found on southern exposures, but at somewhat higher elevations (4,800 to 6,500 feet). *Pinus contorta* and *Larix occidentalis* are major dominants in seral stands, and *Pinus ponderosa* is absent or only a minor component. *Vaccinium globulare* is usually well represented, and *Xerophyllum* is common. Most stands in this phase were classified as *Pseudotsuga/Xerophyllum* h.t. in our preliminary publications (1972 and 1974).

Vaccinium globulare (VAGL) phase.--In contrast to the other phases, this one is commonly associated with the continental mountain climate found near and east of the Continental Divide in Montana. It was sampled in central Montana and also locally in an area immediately southeast of Missoula. Unlike the other phases, it is restricted to cool exposures (northwest, north, and east), where it occupies moderately steep slopes. Elevations of sample stands ranged from 6,200 to 6,800 feet in central Montana and from 5,000 to 5,600 feet near Missoula. *Pinus contorta* is a major component of seral stands; additionally, *Larix occidentalis* and *Pinus ponderosa* are minor components of the stands near Missoula. *Arctostaphylos* and *Xerophyllum* are scarce in the undergrowth, although *Vaccinium globulare* is well represented. *Arnica latifolia,* indicative of colder climatic conditions, is common in some stands.

Soil.--Our stands were on a variety of noncalcareous parent materials (appendix D-1). Surface soils were very gravelly sandy loams to silts in the *XETE* phase; gravelly silty clay loams in the *ARUV* phase, and gravelly loams to silts in the *VAGL* phase. Soils were acidic in all phases. Ground surfaces had little rock or bare soil exposed; duff depths averaged about 3 cm.

Productivity/Management.--Timber productivity is low to moderate (appendix E). Silvicultural prescriptions and choice of species will vary depending on the phase. This habitat type receives little use by domestic stock. Deer and elk use is light to moderate.

This is an important habitat type for production of *Vaccinium globulare*, whose berries are utilized by bears, grouse, other wildlife, and humans, and whose shoots are browsed by big game. Miller (1977) studied the response of *Vaccinium globulare* to prescribed fires in spring and fall on a site in the *Arctostaphylos* phase in west-central Montana. Her findings should be useful for predicting response of *Vaccinium globulare* to management activities.

This *PSME/VAGL* h.t. includes a combination of stands formerly classified as *Pseudotsuga/Vaccinium globulare* h.t. and *Pseudotsuga/Xerophyllum tenax* h.t. (fig. 57, page 137) in our preliminary classifications. In final analysis it seemed most realistic to treat these situations as three phases of one habitat type.

Other studies.--Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have identified a few stands as this habitat type in central Idaho; it has evidently not been noted or recognized elsewhere.

Pseudotsuga menziesii/Linnaea borealis h.t.
(PSME/LIBO; Douglas-fir/twinflower)

Distribution.--*PSME/LIBO* is a major habitat type in northwestern, west-central, and central Montana, where it occurs on relatively moist sites for the *Pseudotsuga* series. It often forms a transition between this series and the *Picea, Abies grandis*, or *Abies lasiocarpa* series. This type is usually found on moderate slopes and all but the driest (southeast to west) aspects. Elevations vary by phase, but are mostly 2,600 to 4,000 feet in northwestern, 4,000 to 6,000 feet in west-central, and 5,000 to 6,500 feet in central Montana.

Vegetation.--*Pseudotsuga* forms the climax and is also a vigorous member of seral communities. *Pinus contorta* is a major component of young stands throughout the *VAGL* and *CARU* phases--collectively the cooler sites within this habitat type. *Larix occidentalis* and *Pinus ponderosa* are often components of seral stands in northwestern and west-central Montana, but are absent eastward.

Undergrowth in all three phases is characterized by a mat of *Calamagrostis rubescens* in which *Linnaea borealis* is common. Also, *Arctostaphylos uva-ursi, Spiraea betulifolia,* and *Arnica cordifolia* or *A. latifolia* are typically found. Other characteristics of the undergrowth vary by phase.

Calamagrostis rubescens (CARU) phase.--This phase occupies relatively cold, dry sites within the habitat type. It occurs mostly in west-central and central Montana at 4,800 to 6,000 feet on cool exposures, but is found as high as 7,250 feet in the Big Hole River drainage of southwestern Montana. *Pinus contorta* is a major component of seral stands. Undergrowth is distinguished by scarcity of *Vaccinium globulare* and *Symphoricarpos albus*. *Vaccinium scoparium* is often well represented, showing this phase's resemblance to the neighboring (colder) *ABLA/LIBO* h.t., *VASC* phase. The undergrowth in representation of *Arnica latifolia* and moist-site forbs *Osmorhiza chilensis, Smilacina stellata,* and *Thalictrum occidentale* is intermediate between that of the *SYAL* and *VAGL* phases.

Symphoricarpos albus (SYAL) phase.--The *SYAL* phase occurs on benches and cool exposures having moist and mild-temperature environments. It was sampled at 2,600 to 3,800 feet in northwestern, 4,000 to 5,000 feet in west-central, and near 6,000 feet in central Montana. In contrast to other phases, *Pinus contorta* is seldom a component of seral stands. *Symphoricarpos albus* is well represented in the undergrowth, while *Vaccinium globulare, V. scoparium,* and *Xerophyllum* are poorly represented. *Arnica cordifolia* is common and *A. latifolia* rare, reflecting warmer environmental conditions. Also, moist-site forbs *Osmorhiza chilensis, Smilicina stellata,* and *Thalictrum occidentale* are conspicuous in this phase.

Vaccinium globulare (VAGL) phase.--This phase occupies the coolest, most moist sites within the habitat type; it was found mostly in west-central Montana between 4,250 and 6,000 feet elevation on cool exposures. *Pinus contorta* is a major component of seral stands, and *Vaccinium globulare* is well represented in the undergrowth. The coolness of these sites is indicated by the presence of *Xerophyllum* in about half of the sample stands and by *Arnica latifolia* being as abundant as *Arnica cordifolia;* the phase thus shows an affinity with the *Abies lasiocarpa* series.

Soil.--Our stands were on a variety of primarily noncalcareous parent materials (appendix D-1). Surface soils were acidic, gravelly sandy loams to silty clay loams. Little rock or bare soil were exposed. Duff depths averaged 4.6 cm in the *SYAL* phase, 6.1 cm in the *CARU* phase, and 3.5 cm in the *VAGL* phase.

Productivity/Management.--Timber productivity is moderate in western Montana, and low to moderate eastward (appendix E). The highest productivities were in the *CARU* phase. The prevalence of *Calamagrostis rubescens* in all phases should be considered in site preparation plans. However, competition for moisture should be less severe than in the *PSME/CARU* and *PSME/SYAL* h.t.s. Light to moderate use by deer and often by elk was evident in most sample stands.

Other studies.--Two sample stands from R. and J. Daubenmire's (1968) *Pseudotsuga/Calamagrostis* h.t. contained *Linnaea borealis* and appear similar to our *PSME/LIBO* h.t. Ogilvie's (1962) *Pseudotsuga/Arctostaphylos* h.t. contained *Linnaea* and is also similar.

Pseudotsuga menziesii/Symphoricarpos albus h.t.
(*PSME/SYAL*; Douglas-fir/snowberry)

Distribution.--*PSME/SYAL* is one of the more common habitat types and is found throughout Montana on moderately warm slopes and benches. Occasionally it occurs on northerly aspects near the lower distribution of *Pseudotsuga* in the foothills of drier mountain ranges.

Vegetation.--Seral stands at lower elevations are frequently dominated by *Pinus ponderosa*. At higher elevations *Pseudotsuga* dominates most stages of succession. Occasionally *Pinus contorta* is a minor seral species. The dominant undergrowth species is usually *Symphoricarpus albus*; variations in undergrowth composition are described for three phases.

Agropyron spicatum (AGSP) phase.--This phase occupies sites on the droughty extreme of the habitat type; stands are somewhat open and often appear similar to those of the three *Pseudotsuga*/bunchgrass h.t.s, reflecting a transitional environment. The phase is generally restricted to west-central Montana, where it occurs on warm, dry southerly exposures. *Agropyron spicatum, Festuca idahoensis*, and/or *Balsamorhiza sagittata* are well represented in undisturbed old-growth stands. *Pinus ponderosa* is a major seral dominant, and *Pinus contorta* and *Larix occidentalis* are absent.

Calamagrostis rubescens (CARU) phase.--Over half of the sample stands in this habitat type had *Calamagrostis rubescens* and *Carex geyeri* as major components of the undergrowth (fig. 18). In northwestern and west-central Montana elevations were mostly between 2,700 and 5,500 feet. Eastward, elevations of sample stands were higher (5,300 to 7,000 feet). *Pinus ponderosa* is a seral dominant in northwestern and west-central Montana. *Pinus contorta* is a minor seral component, increasing in abundance to the east. *Larix occidentalis* is generally absent. In many stands *Pseudotsuga* dominates most stages of succession.

No consistent environmental differences were found to distinguish this phase from the *SYAL* phase. However, the abundance of rhizomatous graminoids seems important to recognize.

Symphoricarpos albus (SYAL) phase.--Bunchgrasses, *Calamagrostis rubescens*, and *Carex geyeri* are poorly represented in old-growth stands. Elevations of sample stands ranged from 3,600 to 6,400 feet west of the Continental Divide and from 4,800 to 7,200 feet eastward. *Pinus ponderosa* is a major seral component on sites within its range, while *Pinus contorta* and *Larix occidentalis* are essentially absent. In many stands *Pseudotsuga* dominates most stages of succession.

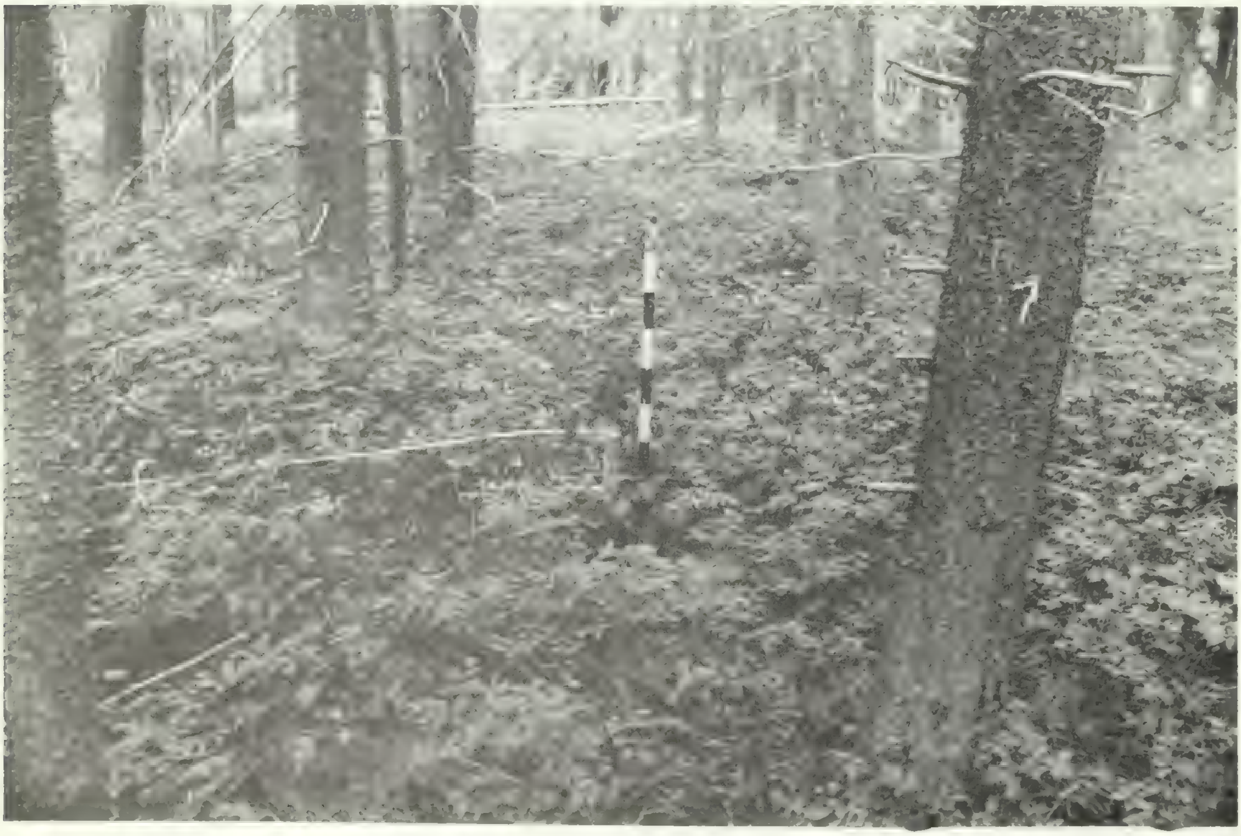


Figure 18.--Pseudotsuga menziesii/Symphoricarpos albus *h.t. (*Calamagrostis *phase) on a broad ridge (6,000 feet elev.) in the Big Belt Mountains east of Townsend in central Montana. Seral* Pinus contorta *dominates the overstory along with some* Pseudotsuga; Symphoricarpos *and* Calamagrostis *dominate the undergrowth.*

Soil.--The *PSME/SYAL* h.t. was sampled on a variety of calcareous and noncalcareous parent materials (appendix D-1). Surface soils were gravelly (33 percent) sandy loams to silts with acidic reactions (slightly basic on some of the calcareous parent materials). Little surface rock was evident in the *CARU* and *SYAL* phases, although an average of 7 percent was noted in the *AGSP* phase. Only small amounts of bare soil were exposed; duff depth averages 2.6 cm in the *AGSP* phase, 3.6 cm in the *CARU* phase, and 4.1 cm in the *SYAL* phase.

Productivity/Management.--Timber productivity of this type ranges from low to high in western Montana and from low to moderate eastward (appendix E). Basal area stocking is good in the *CARU* and *SYAL* phases, but the *AGSP* phase may have stockability limitations and also has the lowest site index values. Regeneration may be difficult in the droughty *AGSP* phase. The prevalence of rhizomatous graminoids in the *CARU* phase should be considered in site preparation plans.

Moderate use by deer and occasionally by elk and moose was evident in most stands in the *CARU* and *SYAL* phases.

Other studies.--Our *SYAL* phase is similar to most of R. and J. Daubenmire's (1968) *Pseudotsuga/Symphoricarpos* h.t.; two of their stands are similar to our *CARU* phase. Ogilvie's (1962) *Pseudotsuga/Symphoricarpos* h.t. and the part of his *Pseudotsuga/Calamagrostis* h.t. having *Symphoricarpos* "well represented" are comparable to our *CARU* phase. Most of Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) *PSME/SYAL* h.t. in central Idaho is also comparable to our *CARU* phase.

Pseudotsuga menziesii/Calamagrostis rubescens h.t.
(*PSME/CARU*; Douglas-fir/pinegrass)

Distribution.--*PSME/CARU* is the most ubiquitous habitat type in the *Pseudotsuga* series in Montana. It occurs on moderately dry mountainsides and upper slopes. At the lower elevations it often occupies northerly aspects or benches, shifting to southerly positions at high elevations. It often represents the highest extension of the *Pseudotsuga* series.

Vegetation.--Seral tree species include *Pinus ponderosa, Pinus contorta, Larix occidentalis*, and occasionally *Pinus albicaulis*. As shown in figure 19, tree composition varies considerably by phase; *Pseudotsuga*, however, succeeds quite well and dominates most stands. Old-growth stands often have a park-like appearance.

Undergrowth composition also varies by phase; however, some features are characteristic of the habitat type in general. As R. and J. Daubenmire (1968) have noted, the undergrowth is a brilliant green grassy layer with uniformity enhanced by the lack of inflorescences. *Carex geyeri* is often well represented and may even dominate *Calamagrostis*. *Arctostaphylos uva-ursi* is occasionally well represented. The most abundant forb in the 97 sample stands was *Arnica cordifolia*; other characteristic forbs include *Antennaria racemosa, Aster conspicuus*, and *Fragaria virginiana*. *Spiraea betulifolia* is occasionally well represented, but such stands were similar in other respects to stands having little or no *Spiraea*. Therefore, we gave *Spiraea* less weight as an indicator than *Calamagrostis rubescens*, unlike R. and J. Daubenmire (1968) and Robert Steele and others (1975 preliminary draft of forest habitat types of central Idaho, USDA Forest Service, Intermountain Station).

Figure 19 shows some of the major vegetational differences among the four phases of this habitat type. The elevation distributions of these phases are shown in table 2.

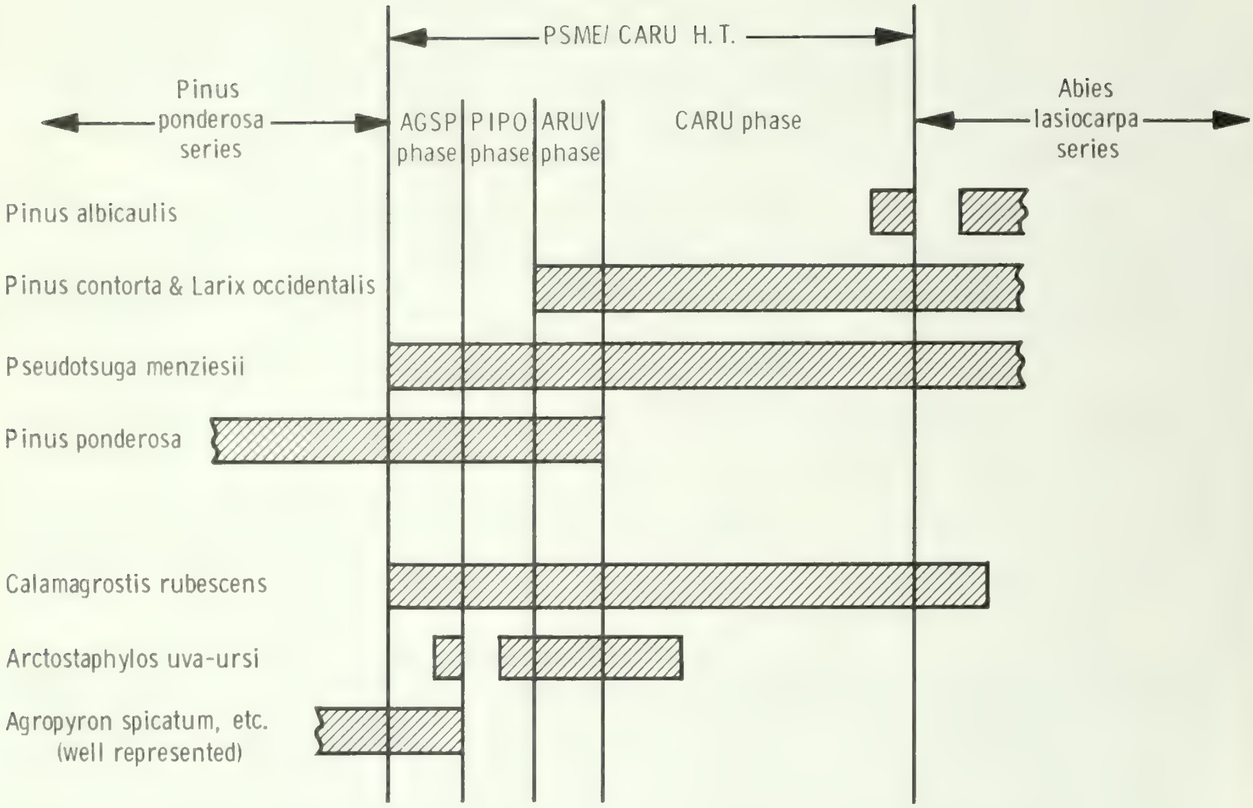


Figure 19.--Generalized distribution of key indicator species within phases of the Pseudotsuga/Calamagrostis *habitat type.*

Table 2.--*Elevational range (in feet) of* Pseudotsuga/Calamagrostis *h.t. sample stands by phase in geographic subdivisions of Montana (as shown in fig. 1)*

Phase of the habitat type	Geographic subdivision of Montana: Northwestern	West-central and central	Southwestern and south-central
AGSP	2,700 to 3,500	4,400 to 5,300	none
PIPO	3,500 to 4,800	4,800 to 6,000	none
ARUV	3,000 to 4,000	4,000 to 5,400	none
CARU	4,700 to 5,300	5,300 to 7,000	6,500 to 7,800

Agropyron spicatum (AGSP) phase.--This phase is most common in west-central Montana where it occupies the droughty extremes of the *PSME/CARU* h.t. Bunchgrasses *Agropyron spicatum*, *Festuca idahoensis*, or *F. scabrella*, are well represented and not obviously seral in mature stands. Also in contrast to other phases, *Balsamorhiza sagittata* is usually well represented on these sites. *Pinus ponderosa* is the major seral component of the overstory, and *Pinus contorta* and *Larix occidentalis* are absent on these dry sites. *Pseudotsuga* increases its coverage slowly beneath pine-dominated stands. This phase represents a transitional environment between the *PSME/CARU* and the various *PIPO/* or *PSME*/bunchgrass h.t.s.

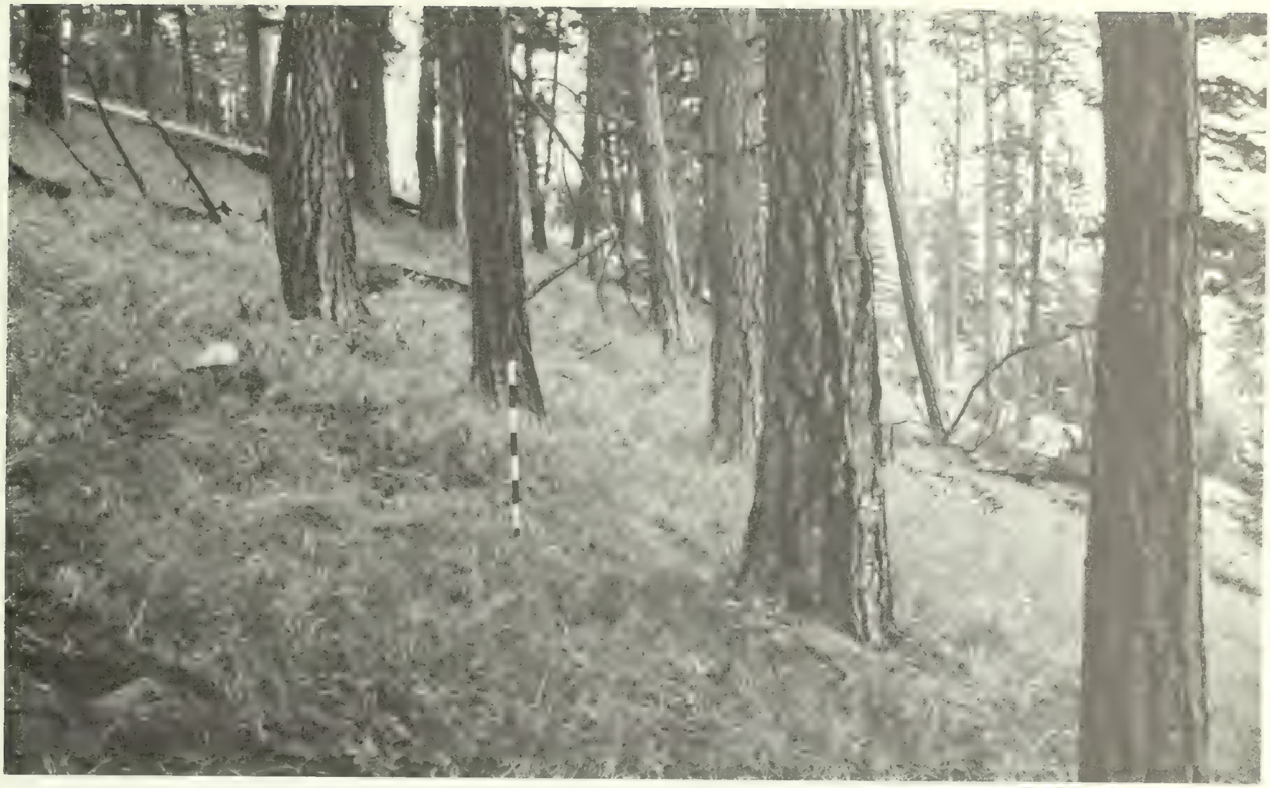


Figure 20.--Pinus ponderosa *phase (*PSME/CARU *h.t.) on a steep south-facing slope (4,550 feet elev.) southwest of Eureka in northwestern Montana.* Pinus ponderosa *is the long-lived seral dominant.*

In contrast to other phases in the *PSME/CARU* h.t., *Calamagrostis rubescens* decreases following overstory removal. Sites apparently become too dry and warm for *Calamagrostis* and it will become well represented again only as the overstory closes, creating a cooler microclimate.

Pinus ponderosa (PIPO) phase.--This warm phase is found mostly between 4,500 and 6,000 feet elevation on south-facing slopes (fig. 20). It is common in west-central and northwestern Montana, and occurs locally in central Montana. It is similar to the *AGSP* phase in that it does not support *Pinus contorta* or *Larix occidentalis* (fig. 19), but is less droughty. *Pinus ponderosa* is common (≥ 10 trees/acre) and typically codominant with *Pseudotsuga* under seral conditions.

Indicators for the *Agropyron spicatum* phase are poorly represented in mature stands. *Calamagrostis rubescens* may or may not maintain high coverage after logging or fire. In contrast to the usual situation for the habitat type, *Calamagrostis rubescens* flowers profusely in some of the relatively open but undisturbed stands. This phase is bordered upslope by the cooler *CARU* phase.

Arctostaphylos uva-ursi (ARUV) phase.--This phase occurs on warm, well-drained benches and gentle slopes. Topographically and climatically these sites are similar to but slightly drier than those of the *PSME/VACA* h.t. This minor phase is common in west-central Montana and is found occasionally in northwestern Montana, as well as on the Helena National Forest in the central part of the State.

These stands are typically dominated by seral *Pinus ponderosa*; however, small amounts of *P. contorta* or *Larix occidentalis* are also present, reflecting more moisture than the other warm phases (*AGSP* and *PIPO*) of the habitat type.

Arctostaphylos uva-ursi, Calamagrostis rubescens, and *Carex geyeri* form the dominant undergrowth. In a few seral stands *Calamagrostis* is not well represented, but nevertheless is common.

This phase should not be confused with the *PSME/ARUV* h.t., which is found on distinctly drier sites in central Montana.

Calamagrostis rubescens (CARU) phase.--This phase makes up the bulk of the *PSME/CARU* h.t. (62 out of the 97 sample stands) (fig. 21). *Calamagrostis rubescens* is well represented, and bunchgrasses are poorly represented in mature stands, although they may increase with disturbance. As shown in table 2, elevations are higher than for the other phases, and the sites are too cold for any appreciable representation of *Pinus ponderosa*. Drought is evidently less severe than in the *AGSP* and *PIPO* phases, allowing *Pinus contorta* to become a seral component of many stands. *Larix occidentalis* is found in some stands in northwestern Montana. East of the Continental Divide, *Pinus albicaulis* may be well represented at the upper limits of this phase.

Soil.--Our stands were on a variety of primarily noncalcareous parent materials (appendix D-1). Surface soils were acidic, ranging in texture from gravelly sandy loams to gravelly silts. Surface rock exposure averaged 5 to 6 percent in the *AGSP* and *ARUV* phases and 2 to 3 percent in the *CARU* and *PIPO* phases. Bare soil exposure was minimal and duff depth averaged about 4 cm in all phases.

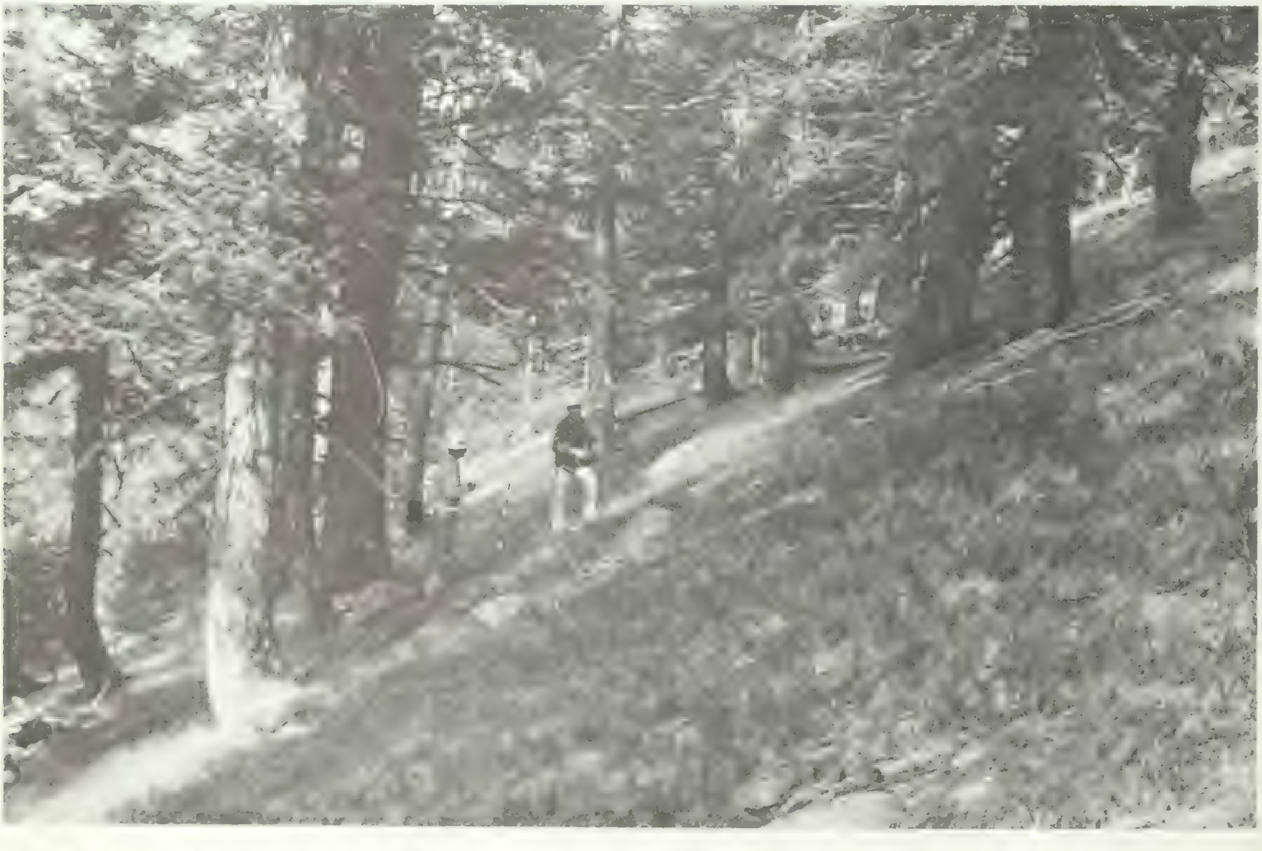


Figure 21.--Calamagrostis *phase* (PSME/CARU *h.t.) on a steep southwest exposure (6,900 feet elev.) southwest of Missoula. This site is above the cold limits of* Pinus ponderosa

Productivity/Management.--Timber productivity is low to moderate in the *PSME/CARU* h.t. (appendix E). The *ARUV* phase averaged highest in productivity; the *CARU* phase was lowest. Clearcutting and shelterwood systems will favor seral species, while partial cutting will lead to eventual dominance by *Pseudotsuga* in most cases. Extensive scarification may be needed to reduce grass competition for successful regeneration.

Although forage production is low, cattle and horse use is evident on many gentle slopes. Moderate winter use by deer and elk is apparent in the *AGSP* and *ARUV* phases. The *PIPO* and *CARU* phases show light to moderate use, evidently in spring and fall.

Other studies.--Similar habitat types have been described from Wyoming (Cooper 1975) and central Idaho (Robert Steele and others, 1975 preliminary draft, USDA Forest Service, Intermountain Station) to Alberta (Ogilvie 1962), British Columbia (Brayshaw 1965; McLean 1970), northern Idaho, Washington (R. and J. Daubenmire 1968), and eastern Oregon (Hall 1973).

Pseudotsuga menziesii/Carex geyeri h.t.
(*PSME/CAGE*; Douglas-fir/elk sedge)

Distribution.--The *PSME/CAGE* h.t. is similar to but apparently somewhat drier than the *PSME/CARU* h.t. East of the Continental Divide *PSME/CAGE* is locally abundant, but is much less common than *PSME/CARU*. Limited areas of it are found in west-central Montana. Stands are generally between 6,100 and 7,600 feet in elevation on mid- and upper slopes having southern exposure. *PSME/CAGE* may be an ecological replacement for *PSME/CARU* beyond the limits of *Calamagrostis rubescens*, especially in south-central Montana. Elsewhere *PSME/CAGE* often occurs on south exposures, adjacent to north-facing *PSME/CARU* sites.

Vegetation.--*Pseudotsuga* is normally the only coniferous tree in seral stands. Many sites are above the elevational limits of *Pinus ponderosa* and are too dry for *Pinus contorta*. *Pinus flexilis* was present in one stand with limestone parent material, and *Pinus albicaulis* was codominant with *Pseudotsuga* in another high-altitude stand approaching subalpine conditions.

Carex geyeri is usually abundant and *Arnica cordifolia* well represented. Small quantities of *Juniperus communis* and *Spiraea betulifolia* often occur, along with many species of forbs including *Osmorhiza chilensis*, *Thalictrum occidentale*, and *Smilacina racemosa*. *Calamagrostis rubescens* is poorly represented on these dry sites.

Soil.--Our stands were on calcareous and noncalcareous parent materials of sedimentary and metamorphic origin (appendix D-1). Surface soils were acidic to slightly basic, gravelly (42 percent) sandy loams to silts. Little surface rock or bare soil were exposed; duff depth averaged 4.7 cm.

Productivity/Management.--Management implications are similar to those for the *PSME/CARU* h.t., *CARU* phase, although timber productivity is somewhat less (appendix E-4). Regeneration may also be more difficult on these drier sites and overstory species manipulations are essentially restricted to *Pseudotsuga*. Evidence from sample plots suggests that this habitat type receives moderate use by mule deer.

Other studies.--A *PSME/CAGE* h.t. was not recognized by R. and J. Daubenmire (1968), *Carex geyeri* being considered an ecological equivalent of *Calamagrostis*. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) report extensive occurrence of the *PSME/CAGE* h.t. in central Idaho.

Pseudotsuga menziesii/Spiraea betulifolia h.t.
(*PSME/SPBE*; Douglas-fir/white spiraea)

Distribution.--This minor habitat type is found on relatively warm, dry slopes at lower elevations--generally 3,500 to 4,200 feet in west-central Montana and 5,300 to 5,800 feet east of the Continental Divide. Aspect is mostly south and west, but may be north at lowest elevations or on limestone substrates.

Vegetation.--*Pinus ponderosa* is usually a major seral dominant, except in areas such as north of Rogers Pass (southwest of Great Falls) where severe winter winds and widely fluctuating temperatures cause "red belt" mortality. Undergrowth associates of *Spiraea* include *Arnica cordifolia*, *Aster conspicuus*, *Fragaria virginiana*, *Allium cernuum*, and *Berberis repens*. Sites are apparently too dry for appreciable amounts of *Calamagrostis rubescens*, *Carex geyeri*, or *Symphoricarpos albus* to develop.

Soil.--Our stands were on calcareous and noncalcareous sedimentary and metamorphic parent materials (appendix D-1). Surface soils were acidic to slightly basic gravelly (40 percent) sandy loams to silts. A moderate amount of surface rock (5 percent) was evident, but little bare soil was exposed. Duff depth averaged 2.5 cm.

Productivity/Management.--Timber productivity of the *PSME/SPBE* h.t. is moderate in western Montana but low eastward (appendix E.) Most sample stands had evidence of moderate use by mule deer.

Other studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) defined a broader *PSME/SPBE* h.t. for central Idaho which may contain considerable amounts of *Calamagrostis*. R. and J. Daubenmire (1968) treated *Spiraea betulifolia* as an ecological equivalent of *Symphoricarpos albus*.

Pseudotsuga menziesii/Arctostaphylos uva-ursi h.t.
(*PSME/ARUV*; Douglas-fir/kinnikinnick)

Distribution.--*PSME/ARUV* is one of the warmest and driest habitat types in the *Pseudotsuga* climax series. It is found mostly in central Montana between elevations of 4,600 and 5,600 feet on the Helena National Forest, and between 4,700 and 6,500 feet on the east Lewis and Clark National Forest. Aspect is generally south, and stands often occur on calcareous substrates.

Vegetation.--*Pinus ponderosa* is a major seral associate of *Pseudotsuga*. Scattered individuals of *Pinus flexilis* may occur on sites having limestone parent material. Sites are apparently too dry for *Pinus contorta*.

Arctostaphylos uva-ursi and *Juniperus communis* are dominants in the undergrowth. *Spiraea betulifolia* is often well represented, and dry-site species including *Agropyron spicatum*, *Festuca idahoensis*, *F. scabrella*, *Apocynum androsaemifolium*, *Balsamorhiza sagittata*, and *Lithospermum ruderale* are common.

Soil.--Our stands were on calcareous and noncalcareous sedimentary and metamorphic parent materials (appendix D-1). Surface soils were acidic to slightly basic gravelly (36 percent) loams to silt loams. Little rock and moderate (5 percent) bare soil were exposed; average duff depth was 6.0 cm.

Productivity/Management.--Timber productivity is low (appendix E). High soil-surface temperatures coupled with low soil moisture may hamper regeneration of logged stands. Stands might be managed for *Pinus ponderosa* using partial cuttings. *Pseudotsuga* appears to be a poor choice for timber production on these sites based on site index comparison (appendix E-1).

Sites are relatively warm and free of snow through much of the winter, and several important big-game forage species are found in this habitat type (appendix C-1). Sample stands showed evidence of moderate to heavy use by mule deer.

Other studies.--This habitat type has not been described elsewhere.

Pseudotsuga menziesii/Juniperus communis h.t.
(*PSME/JUCO*; Douglas-fir/common juniper)

Distribution.--The *PSME/JUCO* h.t. is locally abundant in central and southwestern Montana, mostly at 6,400 to 7,100 feet on the Deerlodge, 5,300 to 6,800 feet on the Lewis and Clark (fig. 22), and 7,500 to 7,800 feet on the Beaverhead National Forest. It is found on gentle, north-facing slopes on decomposed granite substrates on the Deerlodge National Forest. On the Lewis and Clark National Forest, moderately steep south exposures with limestone substrates are typical sites. The general environment is cool and dry or excessively well-drained.

Vegetation.--*PSME/JUCO* is apparently one of the driest habitat types in the *Pseudotsuga* series that still supports *Pinus contorta*. On granitic substrates *Pinus contorta* is a persistent seral species and succession to *Pseudotsuga* is very slow. In contrast, on calcareous parent materials *Pinus contorta* and *Pinus flexilis* are only minor seral components, with *Pseudotsuga* dominating even in young stands.

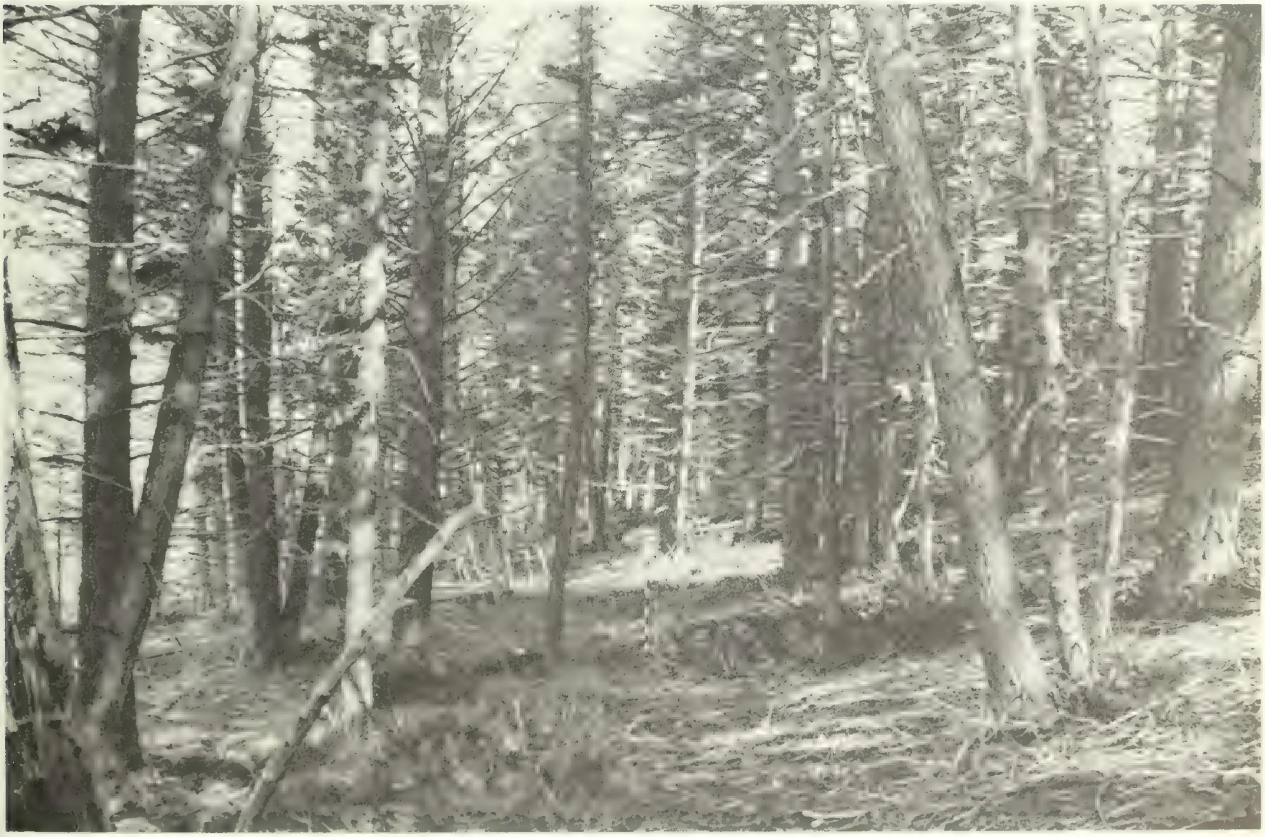


Figure 22.--Pseudotsuga menziesii/Juniperus communis *h.t. on a gentle southwest exposure (6,800 feet elev.) in the Little Belt Mountains northeast of White Sulphur Springs in central Montana. The overstory is pure, old-growth* Pseudotsuga, *and undergrowth is dominated by* Juniperus *and* Arnica cordifolia.

Juniperus communis (occasionally accompanied by *J. horizontalis*) is the dominant undergrowth species. *Arctostaphylos uva-ursi* is often present, but is usually poorly represented. This may indicate some relationship to the *PSME/ARUV* h.t. However, *PSME/JUCO* occupies a cooler environment which supports *Pinus contorta*, while *PSME/ARUV* is characterized by warmer, *Pinus ponderosa*-supporting sites. Small quantities of *Spiraea betulifolia* are often present along with the forbs *Arnica cordifolia*, *Aster conspicuus*, *Astragalus miser*, and *Fragaria virginiana*. Grasses are relatively inconspicuous except in young seral stands.

Soil.--Our stands were on a variety of sedimentary and igneous parent materials (appendix D-1). Surface soils were acidic to slighltly basic, gravelly (27 percent), sandy loams to silts. Little surface rock or bare soil were exposed; duff depth averaged 4.2 cm.

Productivity/Management.--Timber productivity is low to moderate (appendix E). Overstories are strongly even-aged; however, sites appear droughty and regeneration might be difficult to obtain following clearcutting. *Pinus contorta* should be the major species for timber management on granitic substrates, while *Pseudotsuga* should be the primary species on calcareous substrates. *PSME/JUCO* sample stands had been used heavily by mule deer and occasionally by elk. *Juniperus communis* and *J. horizontalis* may be important browse species.

Other studies.--A *PSME/JUCO* h.t. has also been recognized in central Idaho by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station).

Pseudotsuga menziesii/Arnica cordifolia h.t.
(*PSME/ARCO*; Douglas-fir/heartleaf arnica)

Distribution.--*PSME/ARCO* is a cool, dry habitat type occurring on relatively gentle slopes on all aspects from 5,900 to 7,000 feet elevation in central Montana and from 6,700 to 8,000 feet in southwestern Montana (fig. 23). Stands generally appear similar to *PSME/CARU* h.t., *CARU* phase, but they are too dry to support *Calamagrostis* and *Carex geyeri*. Thus, only a dry forb undergrowth remains.

Pseudotsuga is generally the only tree in *PSME/ARCO* stands. Undergrowth is variously dominated by *Arnica cordifolia*, *Antennaria racemosa*, and *Astragalus miser*. In many old-growth or dense younger stands undergrowth is very sparse, and the above species may be poorly represented yet still dominant. *Juniperus communis* and *Fragaria* spp. are also components of the undergrowth. Occasionally *Juniperus* forms large, scattered patches, but it is clearly subordinant to forbs in total coverage. Bunchgrasses *Agropyron spicatum*, *Festuca idahoensis*, and *F. scabrella*, as well as *Poa nervosa* are often weakly represented in old-growth stands and may become abundant following overstory removal.

Soil.--Our stands were on a variety of primarily noncalcareous parent materials (appendix D-1). Surface soils were gravelly (30 percent) sandy loams to silts with reactions ranging from acidic to slightly basic (on limestone). A moderate amount of surface rock (4 percent) was exposed with no bare soil evident; duff depth averaged 4.3 cm.

Productivity/Management.--Timber productivity is low (appendix E). The *PSME/ARCO* h.t. frequently occurs adjacent to montane grasslands, suggesting that severe cutting or burning might result in converting the stand to prairie for a long period. Group selection cutting would probably duplicate the natural regeneration patterns observed in sample stands.

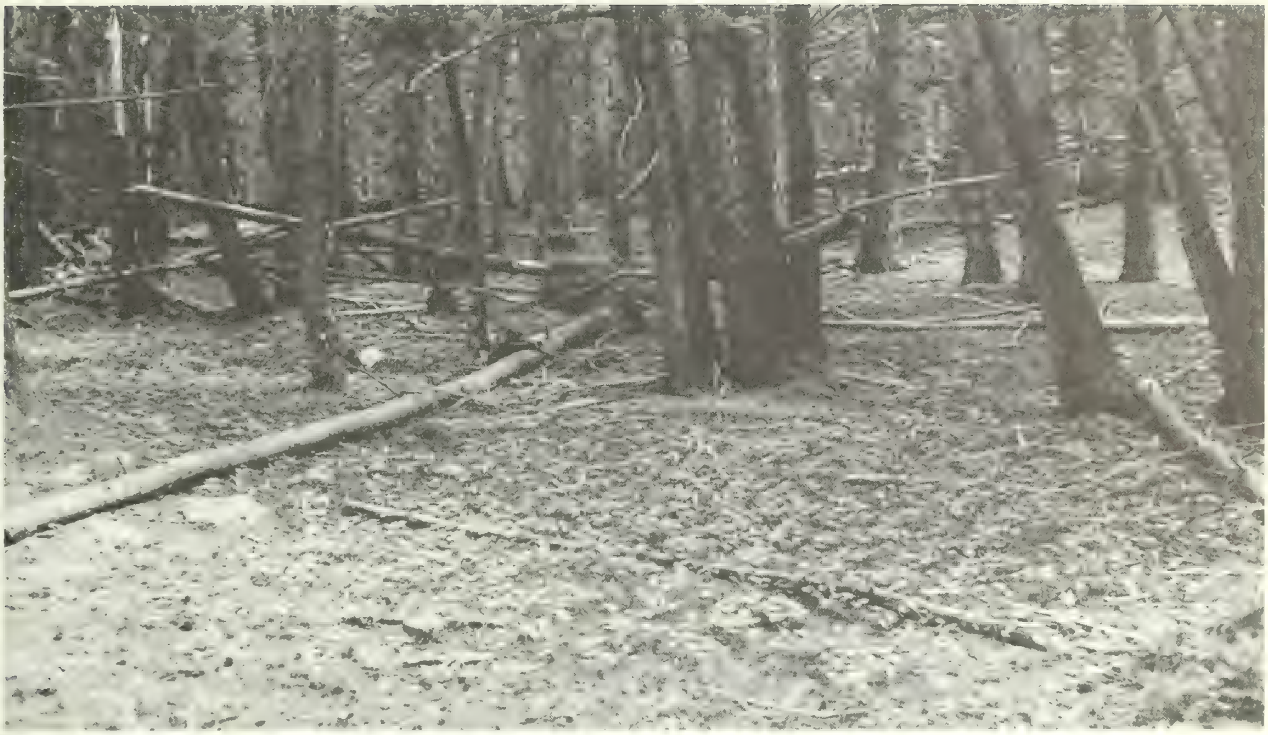


*Figure 23.--*Pseudotsuga menziesii/Arnica cordifolia *h.t. on a gentle northwest exposure (7,050 feet elev.) in a dry mountain range north of Whitehall in southwestern Montana. The overstory is purely old-growth* Pseudotsuga *and undergrowth is principally* Arnica cordifolia.

Young seral stands should provide considerable forage for cattle and big game. Mature stands have a poor representation of forage species but are often used for bedding and cover by both mule deer and domestic stock.

Other studies.--The *PSME/ARCO* h.t. has also been described by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) in central Idaho.

Pseudotsuga menziesii/Symphoricarpos oreophilus h.t.
(*PSME/SYOR*; Douglas-fir/mountain snowberry)

Distribution.--Minor amounts of *PSME/SYOR* were found at two locations in southwestern Montana. These represent eastward extensions of the *PSME/SYOR* h.t., *SYOR* phase that is fairly common in east-central Idaho, according to Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station).

One stand was sampled west of Wisdom in the Bighole River drainage; the other was observed at Cliff Lake on the Madison River. Both sites are on steep south-facing slopes near 6,500 feet. In each case *PMSE/CARU* h.t., *CARU* phase occupies adjacent, less arid sites.

Vegetation.--In both stands the overstory is nearly pure *Pseudotsuga*, and the trees are heavily limbed and rather short. Undergrowth is dominated by *Symphoricarpos oreophilus* along with lesser amounts of *Agropyron spicatum* and *Artemisia tridentata* ssp. *vaseyana;* other species have only minor coverages.

Soil.--Soils observed were shallow, coarse-textured, rocky, and excessively well drained. Parent material was not calcareous.

Productivity/Management.--Timber productivity and management implications are probably similar to those expressed for *PSME/AGSP* h.t. as it occurs in southwestern Montana where *Pinus ponderosa* is absent.

Other studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have provided a more detailed description of this habitat type in central Idaho. Reed (1969, 1976) also described a *Pseudotsuga/Symphoricarpos oreophilus* h.t. in Wyoming which represents a much broader concept.

Picea Series

Distribution.--The *Picea* series is found on moderately moist and cool sites between the *Pseudotsuga* series (drier and warmer sites) and the *Abies lasiocarpa* series (more moist and cooler sites) (fig. 4). It covers a significant percentage of the landscape in the Flathead Valley and in central and south-central Montana. By contrast, elsewhere in the State it is limited to where *Picea* extends down cool ravines slightly below the lower limits of *Abies lasiocarpa.*

In northwestern Montana, as in northern Idaho (R. and J. Daubenmire 1968), *Picea* is often a major component of stands in the *Abies grandis, Thuja,* and *Tsuga* series (appendix B). Going eastward beyond the range of these maritime conifers, *Picea* may replace them.

The occurrence of *Picea* below the limits of *Abies lasiocarpa* may also be related to hybridization of *Picea glauca* and *P. engelmannii* (Daubenmire 1974; Habeck and Weaver 1969). *Picea glauca* is a tree of northern Canada and Alaska whose genetic influence extends south in the Rockies through Montana. In contrast, *Picea engelmannii* is a subalpine Rocky Mountain species whose genetic influence extends northward into southern Canada. Samples of ovuliferous cone scales indicate a range of hybridization in Montana from *P. glauca* X *P. engelmannii* hybrids to pure *P. engelmannii* (table 3). Our limited sample of cone material did not indicate a strong relationship between hybridization and habitat type or geographical area. Therefore, we did not attempt to distinguish species of *Picea* in Montana. We agree with the findings of Daubenmire (1974) that *P. glauca* influence is generally strongest at lower elevations and that of *P. engelmannii* is generally predominant at high elevations.

Vegetation.--Climax stands are dominated by *Picea* but composition of seral stands is variable depending upon geographic area and habitat type. In well-drained *Picea* habitat types in northwestern Montana, *Pseudotsuga, Larix occidentalis,* and *Pinus contorta* are major seral components. East of the Continental Divide, *Pseudotsuga* and *Pinus contorta* are major seral components on similar sites.

Undergrowth composition varies widely among the different *Picea* habitat types. It is often similar to that in comparable *Abies lasiocarpa* or *Pseudotsuga* habitat types.

Soil.--Soils are quite variable in the *Picea* series (appendix D-1). *PICEA/SEST* and *PICEA/PHMA* h.t.s occur primarily on calcareous substrates while *PICEA/CLUN* and *PICEA/VACA* h.t.s were found only on noncalcareous parent materials. Surface rock and bare soil exposure are minimal throughout the series. Duff depths are considerable (average greater than 6 cm) in all types except the *PICEA/VACA* h.t. and the *VACA* phase of *PICEA/CLUN* h.t. Gravel content of surface soils is generally lower and texture finer than in the *Pseudotsuga* series.

Productivity/Management.--The *Picea* series contains some of the better timber-producing lands in Montana. Productivity is moderate to high (appendix E-4) and the sites support several coniferous species. Sites are at moderate elevations, on gentle topography, and are usually accessible. Disadvantages to timber utilization may be that *Picea* series stands are often adjacent to visual corridors, and they provide streamside stability for many watersheds. They are often important habitat for deer, elk, and moose.

Table 3.--*Distribution of* Picea *phenotypes by habitat type and National Forest. Numbers of sample stands dominated by each phenotype are shown below. The hybrid categories are based on percentage free cone-scale length as interpreted from Daubenmire 1974*

Category	P. glauca	P. glauca X P. engelmannii hybrid	P. engelmannii X P. glauca hybrid	P. engelmannii
Percent free cone scale:	<16	16-23	23-30	>30
Habitat type:				
PICEA/EQAR	--	3	3	1
PICEA/CLUN	--	6	4	4
PICEA/PHMA	--	--	1	1
PICEA/GATR	--	2	2	2
PICEA/VACA	1	--	1	1
PICEA/SEST	--	1	7	--
PICEA/LIBO	--	2	5	1
PICEA/SMST	--	--	2	3
Total	1	14	25	13
ABLA/OPHO	--	--	1	1
ABLA/CLUN	--	1	8	7
ABLA/GATR	--	3	10	8
ABLA/VACA	--	2	1	--
ABLA/CACA	--	--	1	3
ABLA/LIBO	--	1	6	2
ABLA/MEFE	--	--	4	13
ABLA/XETE	--	--	1	3
ABLA/VAGL	--	--	2	3
ABLA/VASC	--	--	4	3
ABLA/CARU	--	--	--	2
ABLA/CLPS	--	2	4	2
ABLA/ARCO	--	--	4	1
ABLA/RIMO	--	--	3	1
ABLA-PIAL/VASC	--	--	5	4
ABLA/LUHI	--	--	1	7
PIAL-ABLA	--	--	3	--
Total	0	9	58	60
National Forest:				
Kootenai	--	2	1	14
Flathead	1	6	10	6
Lolo	--	--	3	10
Bitterroot	--	--	3	5
Deerlodge	--	--	1	9
Beaverhead	--	--	2	2
Helena	--	--	1	7
Lewis & Clark (east)	--	6	20	7
Lewis & Clark (west)	--	1	6	10
Gallatin	--	3	24	6
Custer	--	3	9	3
Yellowstone N.P.	--	1	4	1
Glacier N.P.	--	1	6	7
Total	1	23	90	87

Other studies.--Ogilvie (1962) defined several *Picea* habitat types for the Rocky Mountains of Alberta. Thilenius (1972) mentioned forests of *Picea glauca* in the Black Hills and presumably these are *Picea* climax. Small areas of *Picea* habitat types were described by Cooper (1975) and Hoffman and Alexander (1976) in Wyoming and by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) in east-central Idaho.

Picea/Equisetum arvense h.t.
(*PICEA/EQAR*; spruce/common horsetail)

Distribution.--*PICEA/EQAR* is a localized wet-soil habitat type that characteristically develops on flat sites with poor drainage such as broad alluvial valley bottoms (fig. 24). It is similar topographically and edaphically to the *THPL/OPHO* h.t. of northwestern Montana and northern Idaho. Overall the habitat type is rare, but it is locally common in a few areas such as along Sheep Creek north of White Sulphur Springs and in the Flathead Valley. It is found mostly at elevations of 2,900 to 3,600 feet in northwestern Montana and 5,300 to 6,800 feet east of the Continental Divide. Adjacent habitat types are normally other members of the *Picea* or *Pseudotsuga* series on upland sites, or swamps, marshes, or bogs dominated by *Salix, Carex,* or *Typha* on wetter sites.

Vegetation.--*Picea* is usually the only successful coniferous tree species; however, *Pinus contorta* is occasionally well represented on sites having alluvium substrates. High water tables restrict other conifers to drier hummocks. *Populus trichocarpa* or *Betula papyrifera* may be abundant in seral stands.

Undergrowth normally is dominated by *Equisetum* spp. and wet-site forbs and graminoids. *Equisetum arvense* was abundant in seven out of nine sample stands, while *E. scirpoides* dominated another. Other frequent species include *Cornus stolonifera, Carex* spp., *Galium triflorum, Geranium richardsonii, Senecio triangularis, Geum macrophyllum,* and *Streptopus amplexifolius. Athyrium filix-femina, Rubus pubescens, Cornus canadensis,* and *Viola canadensis* were often found in stands in northwestern Montana.

Lysichitum americanum is abundant in some stands near Flathead Lake. It is a coastal (maritime) indicator that becomes scarce and then absent as one travels eastward into the Rockies. *PICEA/EQAR* stands having *Lysichitum* are indicative of milder climatic conditions than those characterizing the rest of the habitat type.

Soil.--Soils are wet throughout the year, often with standing water. Some sites have a thick layer of organic "muck." Other sites have a substrate composed of coarse-textured alluvium. Mineral soil samples were collected in only three stands (appendix D-1). Surface soil reactions were acidic to slightly basic, depending on parent material. Gravel content and texture were variable. Surface rock and mineral soil exposure were minimal; duff depth averaged 7.3 cm.

Productivity/Management.--Timber productivity is moderate (appendix E-4), but conifers other than *Picea* are usually of minor importance. Overstory manipulation requires special constraints because of the wet soils and potential windthrow of residual trees. Road construction and site development present extreme problems related to high water tables, poor drainage, streamside locations, and organic soils.

Use by big game and domestic stock is variable. In general it appears they avoid this habitat during periods of peak soil saturation but may make some use as soils dry out in late summer. Some stands show moderate winter use by deer, elk, and moose.

Other studies.--Ogilvie (1962) described two similar *Picea* habitat types for the Rocky Mountains in Alberta. His *Picea glauca/Equisetum* h.t. appears similar to our variation occurring on alluvial silts. His *Picea glauca/Sphagnum-Ledum groenlandicum* h.t. occurring on acid peat accumulations appears much like our stands growing on deep

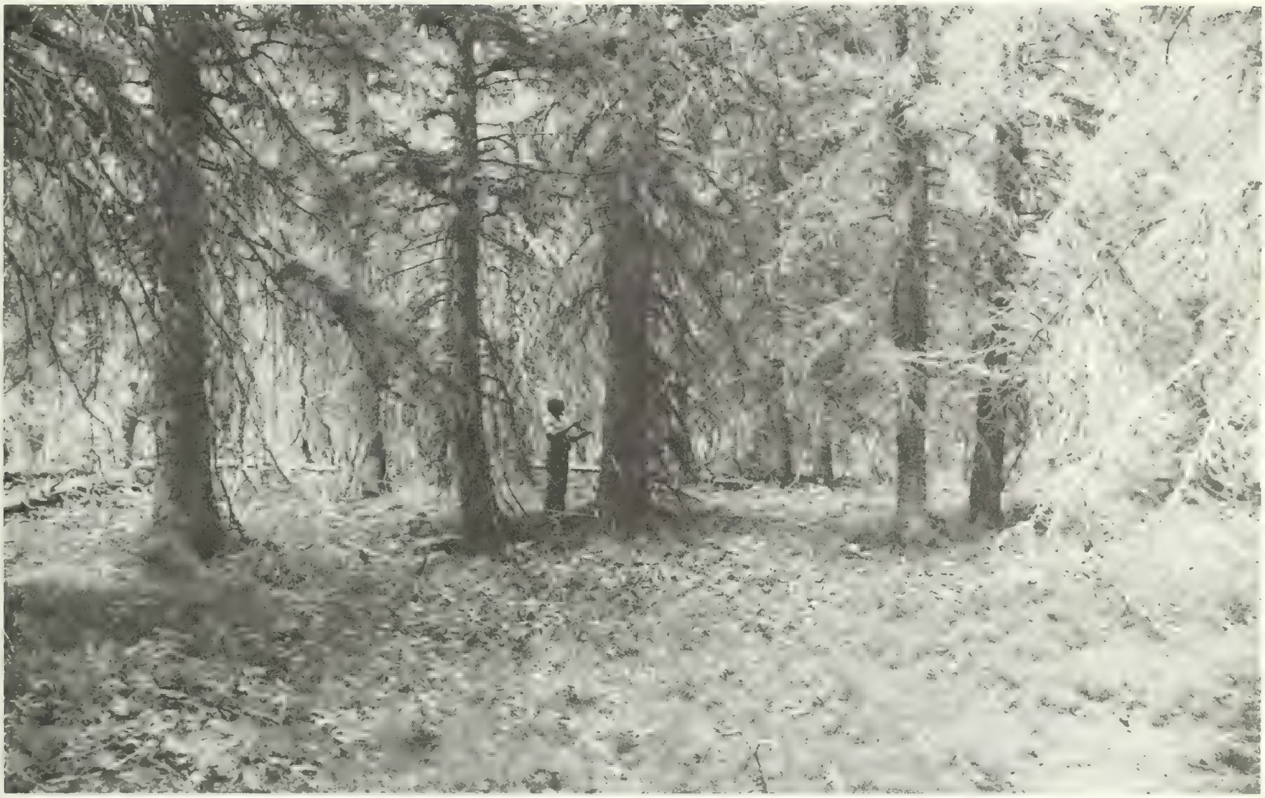


Figure 24.--Picea/Equisetum arvense *h.t. in a stream bottom (5,600 feet elev.) west of Augusta in central Montana. Nearly all the tree growth is* Picea, *and* Equisetum arvense *is the major undergrowth plant.*

organic soils, except that our stands have few shrubs. Bell (1965) used *Lysichitum* to name a wet-site association within the *Tsuga heterophylla* zone in southeastern British Columbia.

Picea/Clintonia uniflora h.t.
(*PICEA/CLUN*; spruce/queencup beadlily)

Distribution.--*PICEA/CLUN* is a moist habitat type found on benches and gentle north slopes in northwestern Montana. It is quite common in the Flathead Valley and is occasionally found to the west in the Kootenai National Forest (fig. 25). Elevations of sample stands ranged from 3,000 to 4,100 feet.

Vegetation.--*Pseudotsuga menziesii, Pinus contorta,* or *Larix occidentalis* often dominate seral stands. Relatively warm and dry sites within this habitat type near Kalispell contain seral *Pinus ponderosa* and have little if any *Pinus contorta.*

Undergrowth is typified by *Clintonia uniflora, Aralia nudicaulis,* or *Cornus canadensis,* and has much in common with *ABGR/, THPL/, TSHE/,* and *ABLA/CLUN* h.t.s of northwestern Montana. Other characteristic species include *Cornus stolonifera, Rubus pubescens, Linnaea borealis, Oryzopsis asperifolia, Adenocaulon bicolor,* and *Galium triflorum.*

The warmest, driest sites in this habitat type lack *Clintonia* but have *Cornus canadensis* and *Galium triflorum.* These sites were included because of the minor area

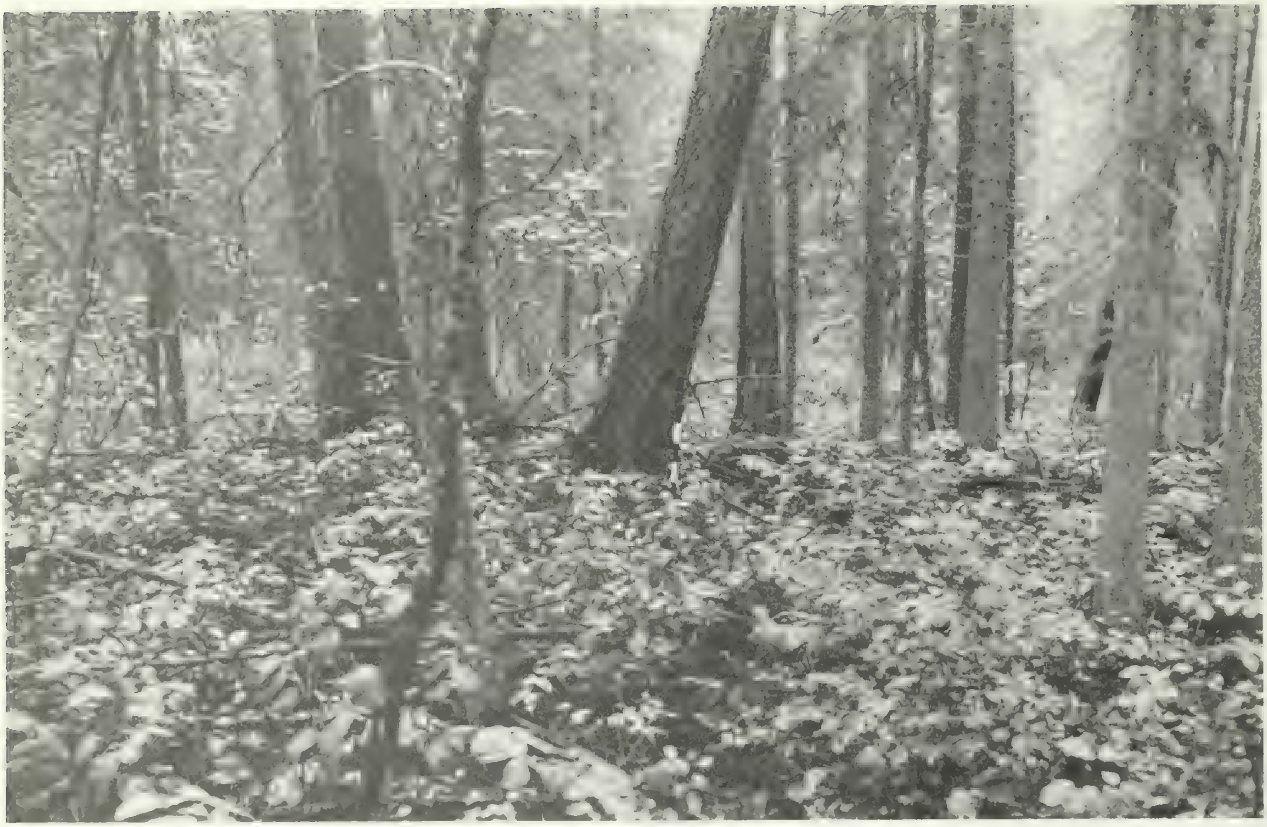


*Figure 25.--*Picea/Clintonia uniflora *h.t. (*Clintonia *phase) in a stream bottom (3,000 feet elev.) southeast of Eureka in northwestern Montana. Seral* Pseudotsuga *and* Larix occidentalis *codominate with* Picea. Aralia nudicaulis *is the most abundant undergrowth.*

they cover as well as their general similarity to the sites supporting *Clintonia*. *Aralia* is usually associated with more moist lowland sites; *Clintonia* occurs on all but the warm, dry margins of the habitat type; and *Cornus canadensis* is found essentially throughout the habitat type.

Clintonia uniflora (CLUN) phase.--This is the typical phase of the habitat type, identified by the absence of *Vaccinium caespitosum*.

Vaccinium caespitosum (VACA) phase.--This phase occurs on gravelly benches and may also be subject to more frequent frosts than the *Clintonia* phase. *Pinus contorta* is a major seral species in natural stands, while *Pseudotsuga* and *Larix* are less important. Basal area stocking is less than in the *CLUN* phase. In general, the *VACA* phase can be considered as transitional to the *PICEA/VACA* h.t.

Soil.--Our stands were on various noncalcareous sedimentary and metamorphic parent materials (appendix D-1), occurring as alluvial or glacial deposits. Surface soils were acidic loams and silt loams with variable gravel content (average 15 percent). Ground surfaces had virtually no rock or bare soil exposed. Duff depth averaged 6.3 cm in the *CLUN* phase, but only 2.6 cm in the *VACA* phase.

Productivity/Management.--Timber productivity is moderate to high (appendix E-3). Productivity was generally highest in the *CLUN* phase. Partial cutting tends to convert overstories to *Pseudotsuga* and eventually *Picea*. Clearcutting and seed-tree cutting will favor *Pinus contorta, Larix, Pseudotsuga,* or *Pinus ponderosa*. The vigorous growth, apparent ease of regeneration, and accessibility of the *PICEA/CLUN* h.t. offer opportunities for intensive timber management. However, much of the area of the habitat type has been cleared for grazing or farming.

PICEA/CLUN often provides winter range for deer, and occasionally elk and moose. Use by domestic stock appears limited in natural stands.

Picea/Physocarpus malvaceus h.t.

(*PICEA/PHMA*; spruce/ninebark)

Distribution.--The *PICEA/PHMA* h.t. covers sizable areas on moist, north-facing slopes in south-central Montana on the Gallatin National Forest (fig. 26). Elevations of sample plots were 5,900 to 7,000 feet.

Vegetation.--*Pseudotsuga menziesii* is the typical overstory dominant in seral stands, with *Pinus contorta* occasionally well represented. In these stands *Picea* is normally represented by scattered but vigorous seedlings, saplings, and poles. *Abies lasiocarpa* is occasionally present at higher elevations in the habitat type; however, both representation and vigor of *Abies* are weak compared with *Picea*.

Symphoricarpos albus and *Spiraea betulifolia* are common associates of *Physocarpus* in the shrub layer. *Actaea rubra* occurs in about half the stands and *Galium triflorum* is usually present; thus, stands would often key to *PICEA/GATR* h.t. except for the shrubby layer of *Physocarpus* that dominates even under mature forest canopies.

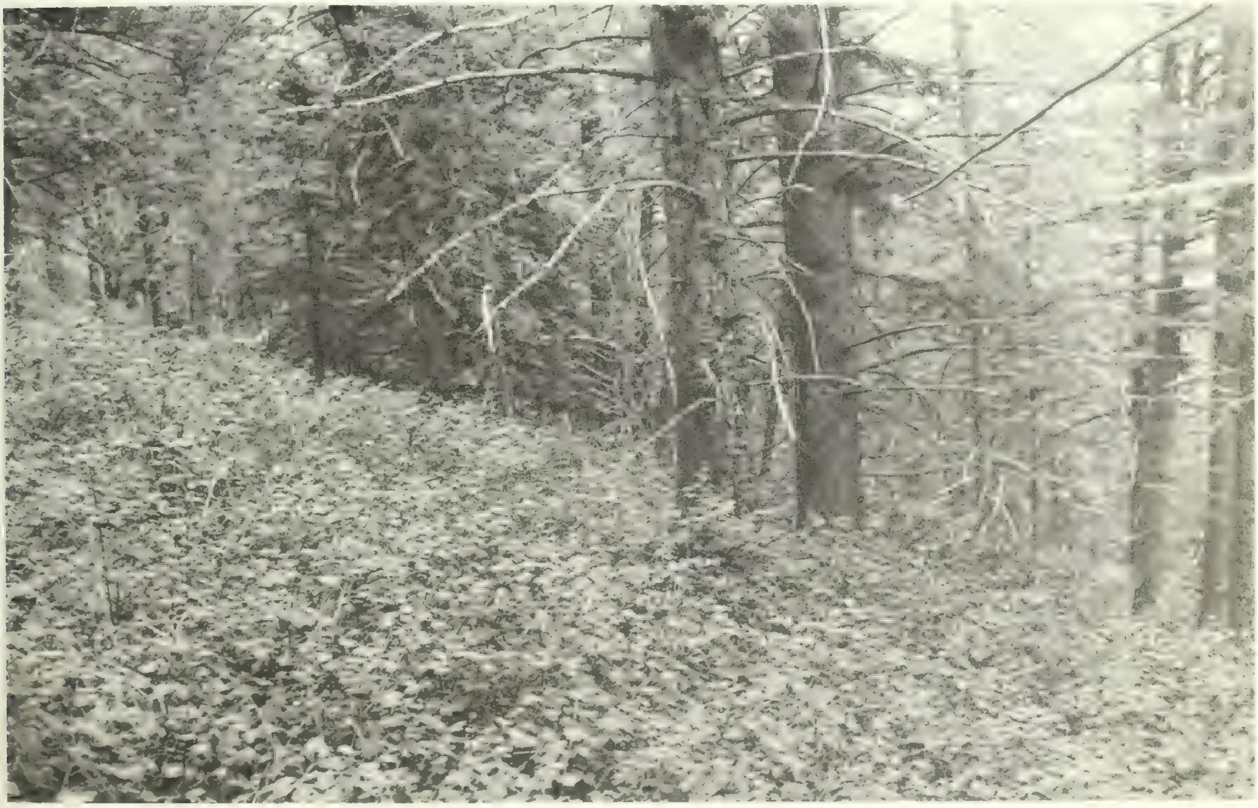


Figure 26.--Picea/Physocarpus malvaceus *h.t. on a moderate east-facing slope (6,600 feet elev.) south of Big Timber in south-central Montana.* Pseudotsuga *dominates the stand, but* Picea *is present in all size classes.*

Soil.--Our stands were primarily on calcareous parent material (appendix D-1). Surface soils were acidic to neutral, gravelly (average 17 percent) loams to silts. Ground surfaces had virtually no rock or bare soil exposed; duff depth averaged 6.5 cm.

Productivity/Management.--This is one of the better habitat types east of the Continental Divide (appendix E-1) for growth of *Pseudotsuga*. Timber productivity is moderate (appendix E-4). Potential for cattle grazing appears poor; however, sample stands showed evidence of considerable use by deer, elk, and moose, often with browsing of *Acer* and *Prunus*.

Other studies.--The *PICEA/PHMA* h.t. has not been described elsewhere in the Rocky Mountains.

Picea/Galium triflorum h.t.
(*PICEA/GATR*; spruce/sweetscented bedstraw)

Distribution.--*PICEA/GATR* is found on cool, moist sites, usually bordering streams, or occasionally on moist toe-slopes. It is abundant only in south-central Montana in the vicinity of the Gallatin National Forest, mostly between 6,000 and 7,000 feet. It is found infrequently elsewhere.

Vegetation.--Seral stands may contain *Pseudotsuga* or *Pinus contorta* in the overstory, but *Picea* reestablishes quickly on disturbed sites and soon dominates. *Abies lasiocarpa* is frequently present in small numbers, but exhibits low vigor.

Undergrowth is composed of various wet-site forbs such as *Galium triflorum, Actaea rubra*, and *Streptopus amplexifolius*. Other characteristic species include *Rubus parviflorus, Ribes lacustre, Symphoricarpos albus, Linnaea borealis, Heracleum lanatum, Smilacina stellata*, and *Geranium richardsonii*. The common occurrence of *Equisetum arvense* testifies to the moist nature of the sites. In general, the undergrowth might be considered as a geographic replacement for the "*Pachistima* union" of northern Idaho (R. and J. Daubenmire 1968) and those habitat types containing *Clintonia* in northwestern and west-central Montana.

Soil.--*PICEA/GATR* was sampled on a variety of primarily noncalcareous parent materials (appendix D-1). Surface soils were loams to silts with reactions ranging from neutral to acidic. Ground surfaces had little rock or bare soil exposed; duff depth averaged 6.8 cm.

Productivity/Management.--Timber productivity is moderate to high (appendix E-4); this is one of the most productive habitat types for *Picea* and *Pinus contorta* east of Divide in Montana. Silvicultural prescriptions leading to all-aged management of *Picea* should be considered as a possible management alternative.

Pellet groups, trails and tracks, and browsing indicate that the habitat type is used by elk and deer as winter range. Some of the broad, flat mountain valleys associated with this type appear to be prime year-round moose habitat. Grazing by domestic stock was light in the sampled stands.

Other studies.--This habitat type has not been described elsewhere in the Northern Rockies.

Picea/Vaccinium caespitosum h.t.
(*PICEA/VACA*; spruce/dwarf huckleberry)

Distribution.--The *PICEA/VACA* h.t. is common in northwestern Montana, especially in the Flathead Valley where sample stands range in elevation from 3,100 to 4,200 feet.

One stand was also sampled near the Sun River Game Range west of Augusta at 5,300 feet. Stands are typically located on gravelly terraces, but sometimes they occupy gentle slopes. Although summer daytime temperatures are probably high on these sites, frost is common. *PICEA/VACA* is probably cooler and perhaps more moist than the *PSME/VACA* h.t., but drier than the *PICEA/CLUN* h.t., *VACA* phase. Eastward in Montana *Vaccinium caespitosum* is usually restricted to benchlands at somewhat higher elevations, where cooler and more moist conditions permit *Abies lasiocarpa* to form the climax (thus, *ABLA/VACA* h.t.).

Vegetation.--*Pseudotsuga menziesii, Larix occidentalis,* and *Pinus contorta* are major seral dominants in this habitat type, and stands seldom reach a near-climax condition. Periodic wildfires seem to recycle stands in which mature *Pinus contorta* has begun to die. In most instances these sites are too cold for *Pinus ponderosa.*

Undergrowth is similar to that of the *PSME/VACA* h.t. A mat of *Calamagrostis rubescens* dominates, and *Vaccinium caespitosum* and *Linnaea borealis* are usually major components of the undergrowth. *Spiraea betulifolia* and *Symphoricarpos albus* may be well represented.

Soil.--Our stands were on noncalcareous parent materials (appendix D-1). Surface soils were slightly acidic, gravelly (30 percent) loams and silt loams. Ground surfaces had virtually no rock or bare soil exposed; average duff depth was only 2.6 cm.

Productivity/Management.--Timber productivity ranges from moderate to high (appendix E-3) with a good mixture of commercially valuable tree species (appendix B). Well-drained soils and gentle topography offer opportunities for intensive timber management. The forage potential for domestic livestock is limited. However, *PICEA/VACA* is evidently used as winter range by elk and mule deer and may provide year-round habitat for moose and white-tail deer.

Other studies.--In Alberta a portion of Ogilvie's (1962) *Picea glauca/Calamagrostis rubescens* h.t. appears similar to our *PICEA/VACA* h.t.

Picea/Senecio streptanthifolius h.t.
(*PICEA/SEST*; spruce/cleft-leaf groundsel)

PICEA/SEST is a minor but distinctive habitat type found in a few limestone mountainous areas of central and southwestern Montana. Sample plots were taken in the Beaverhead Range at 8,300 to 8,600 feet and in the southeastern portion of the Little Belt Mountains at 7,200 to 8,200 feet (fig. 27). One stand was sampled in the Front Range in the Lewis and Clark National Forest at 6,900 feet, and small amounts of it have also been found in the Helena National Forest. Aspects are generally north to east on mid- to upper-slopes or ridgetops. Adjacent sites with deeper soils often support *ABLA/ARCO* h.t., while *PIFL/JUCO* and *PSME/JUCO* occur on warmer exposures.

Vegetation.--Near-climax stands are dominated by *Picea* in all age classes. *Abies lasiocarpa* may be present in minor amounts at higher elevations, but appears incapable of gaining dominance. At lower elevations, *Pseudotsuga* is a major seral dominant. *Pinus flexilis* and *P. albicaulis* are minor seral components.

Undergrowth is primarily composed of small amounts of *Senecio streptanthifolius, Pyrola secunda, Arnica cordifolia, Osmorhiza chilensis, Clematis pseudoalpina, Festuca idahoensis, Trisetum spicatum, Poa nervosa, Poa fendleriana,* and *Juniperus communis.*

Pseudotsuga menziesii (PSME) phase.-- The *PSME* phase is found in central and southwestern Montana. In the Little Belt Mountains it occurs between 7,000 and 7,500 feet. *Pseudotsuga* is a major seral dominant. *Shepherdia canadensis* is also an indicator of this phase.

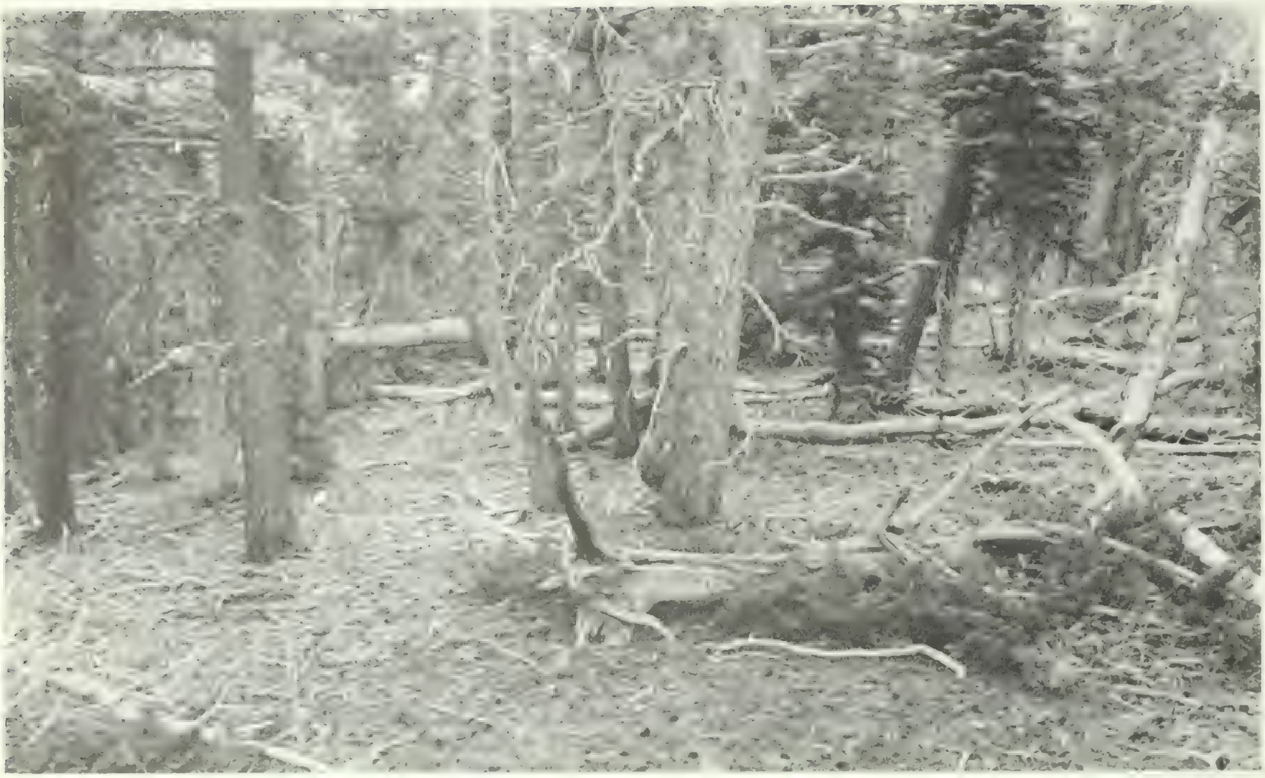


Figure 27.--Picea/Senecio streptanthifolius *h.t.* (Pseudotsuga *phase) on a broad limestone ridge (7,200 feet elev.) northwest of Harlowton in central Montana.* Picea, Pseudotsuga, *and* Pinus flexilis *make up the overstory.* Juniperus communis *is the dominant undergrowth.*

Picea (PICEA) phase.--This phase was found only on the Little Belt Mountains, between 7,500 and 8,200 feet. *Pseudotsuga* is absent because sites are above its elevational limits. *Shepherdia canadensis* is also absent.

Soil.--The *PICEA/SEST* h.t. was found exclusively on calcareous parent materials. Soil samples were not obtained, but field observations indicated soils were shallow and droughty.

Productivity/Management.--Timber productivity is low, making this habitat type the least productive in the *Picea* series (appendix E-4). The sparse undergrowth provides little forage for domestic stock or big game. Some stands show evidence of light use by deer and elk.

Other studies.--This habitat type has not been described elsewhere in the northern Rocky Mountains.

Picea/Linnaea borealis h.t.
(*PICEA/LIBO*; spruce/twinflower)

Distribution.--The *PICEA/LIBO* h.t. is found on cool, well-drained benches and gentle northeast slopes, mostly east of the Continental Divide in Montana. Location and elevation of sample stands are shown in table 4.

Vegetation.--Nearly all of the 21 sample stands apparently became established after wildfires. *Pinus contorta, Pseudotsuga,* and *Picea* dominate stands in that order as succession progresses.

Table 4.--*Distribution of* Picea/Linnaea borealis *h.t. sample stands in Montana*

National Forest vicinity	No. plots	Elevational range
		Feet
Lolo	1	4,200
Deerlodge	2	6,400 to 6,700
Beaverhead	2	6,600 to 7,200
Lewis and Clark (east)	5	5,200 to 6,000
Gallatin	8	5,700 to 7,800
Yellowstone Park	3	6,800 to 7,200

Vaccinium globulare, Vaccinium scoparium, Alnus sinuata, Calamagrostis rubescens, or *Symphoricarpos albus* frequently dominate the undergrowth. *Shepherdia canadensis* often dominates seral stands.

Soil/Climate.--The *PICEA/LIBO* h.t. was sampled on a variety of primarily noncalcareous parent materials (appendix D-1). Surface soils were gravelly (24 percent) sandy loams to silts with reactions ranging from very acidic to slightly basic (mean pH 6.1). Ground surfaces had little rock or bare soil exposed; duff depth averaged 6.4 cm. Weather data from the northeast entrance to Yellowstone Park (appendix D-2) represent this habitat type.

Productivity/Management.--Timber productivity is moderate (appendix E-4). Also, the gentle topography associated with this type offers better opportunity for intensive timber management than many other east-side habitat types.

Elk and deer use was conspicuous in most stands; several stands were also frequented by moose. Use by domestic stock was not observed in any of the sample stands.

Other studies.--This habitat type has not been described elsewhere.

Picea/Smilacina stellata h.t.
(*PICEA/SMST*; spruce/starry Solomon's seal)

Distribution.--*PICEA/SMST* occurs on warm, moist benches and lower slopes. It was sampled only near or east of the Continental Divide at elevations ranging from 4,400 feet on the Helena National Forest to 7,400 feet in Yellowstone Park, but mostly between 5,000 and 7,000 feet.

Vegetation.--*Pseudotsuga* or occasionally *Pinus contorta* dominates in seral stands, giving way to *Picea* as succession advances. Undergrowth is dominated by a luxuriant growth of forbs. *Smilacina stellata, Thalictrum occidentale, Smilacina racemosa, Disporum trachycarpum,* and *Geranium richardsonii* are characteristically present. Sites are evidently too warm for *Linnaea borealis*; but *Calamagrostis rubescens* and *Symphoricarpos albus* commonly dominate the undergrowth as in the *PICEA/LIBO* h.t.

Our observations and those of Herbert Holdorf (Soil Scientist, Lewis and Clark National Forest) indicate that some stands on limestone substrates in central Montana have lower productivity and may even support scattered *Pinus flexilis*, suggestive of *PICEA/SEST* h.t. However, they have luxuriant undergrowth, occur at moderate elevations, and are most logically attributable to the dry margin of the *PICEA/SMST* h.t.

Soil.--Our stands were on a variety of calcareous and noncalcareous parent materials (appendix D-1). Surface soils were mostly gravelly loams to silts. Reactions ranged from neutral to acidic (mean pH 5.9). Ground surfaces had virtually no rock or bare soil exposed; duff depth averaged 6.0 cm.

Productivity/Management.--Timber productivity is moderate (appendix E-4). Several stands showed light use by cattle, and moderate to heavy winter use by deer and elk.

Other studies.--This habitat type has not been described elsewhere.

Abies grandis Series

Distribution.--*Abies grandis* is the indicated climax on many low- to midelevation sites in northwestern and west-central Montana. Its geographic distribution is correlated with the maritime-influence climate, which extends eastward in Montana to Glacier National Park and to the Swan (fig. 28), Clearwater, lower Blackfoot, and Bitterroot river valleys.

This series is bounded on drier sites by the *Pseudotsuga* series and on cooler sites by the *Abies lasiocarpa* series. The overlap of *A. grandis* and *A. lasiocarpa* distributions creates some problems in separating the two series in the field. The distinction is based on competitive potential, rather than presence or absence. Stands with *A. grandis* reproducing more successfully than *A. lasiocarpa* are placed in the *A. grandis* series, and vice versa. Thus, each species may occur in the other series as a seral or minor climax component (appendix B).

Moving westward toward stronger maritime influence, the moist sites are occupied by the *Thuja plicata* series and the *Tsuga heterophylla* series, which reach maximum development in northern Idaho (R. and J. Daubenmire 1968). In frost pockets or on drier sites in the valleys of northwestern Montana, the *Abies grandis* series is occasionally bordered by the *Picea* series.

We recognize three *Abies grandis* habitat types in Montana, which indicates greater environmental diversity near the eastern limits of the series than in northern Idaho, where only one *A. grandis* habitat type has been defined (R. and J. Daubenmire 1968). This increased diversity is even more pronounced near the southern limits of the series in the Nezperce National Forest where six *A. grandis* habitat types have been recognized by Robert Steele and others (1976, preliminary draft, USDA Forest Service, Intermountain Station).

Vegetation.--*Pseudotsuga menziesii* is usually a major component of seral stands. *Larix occidentalis, Pinus contorta, Picea, Pinus ponderosa, Pinus monticola* (roughly in order of decreasing importance) may also occur as seral dominants or components of mixed stands.

The undergrowth is typified by numerous moist-site forbs and a diverse mixture of shrub species which may gain temporary dominance during early successional stages.

Soil/Climate.--Most soils were derived from noncalcareous parent materials (appendix D-1). Intermittent shallow A_2 horizons overlying a dominant B horizon suggest that loess and volcanic ash represent a major contribution to soil development. Surface soils are generally gravelly loams and silt loams with acidic reactions. Ground surfaces have virtually no rock or bare soil exposed; duff depths are moderate (3 to 6 cm).

Some climatic parameters for the *Abies grandis* series are shown in appendix D-2.

Productivity/Management.--Timber productivity in the series ranges from moderate to very high (appendix E-3). Browse production for elk and deer is high during early

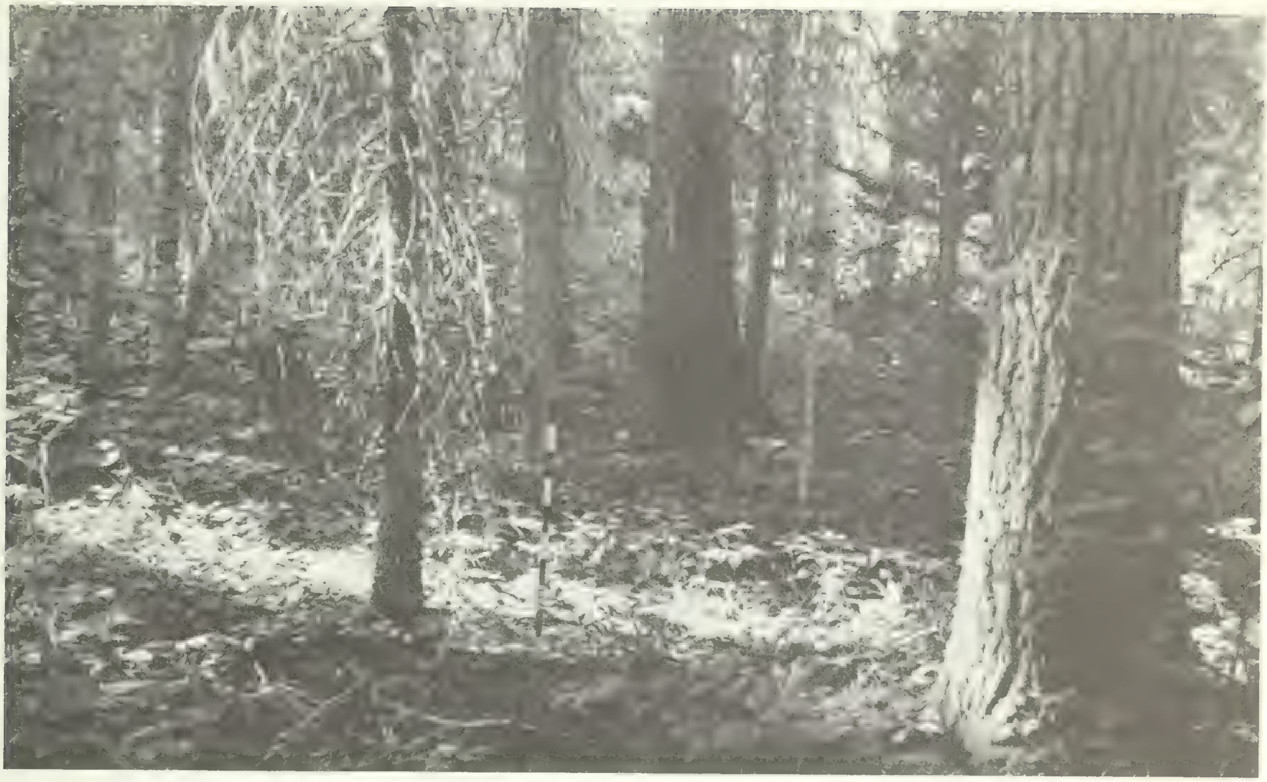


Figure 28.--Abies grandis/Clintonia uniflora *h.t.* (Aralia *phase) in the Swan River Valley of northwestern Montana (3,100 feet elev.).* Abies grandis *and a lesser amount of* Picea *are the only tree species remaining in this near-climax stand.*

successional stages. Some lower elevation sites in the series are utilized as winter range. Forage potential and use for domestic livestock is generally limited to valley bottoms that have been cleared for farming and pastures.

Abies grandis/Clintonia uniflora h.t.
(*ABGR/CLUN*; grand fir/queencup beadlily)

Distribution.--The *ABGR/CLUN* h.t. is found on relatively moist sites from 2,400 to 5,000 feet elevation in northwestern and west-central Montana. It occurs on valley bottoms, benches, and on all aspects.

Vegetation.--*Abies grandis* appears capable of gaining dominance over all other conifers as succession proceeds toward climax. However, in some areas, *Abies lasiocarpa* persists as a minor climax component. Following major disturbance such as fire or logging, *Pseudotsuga, Larix occidentalis,* and *Picea* (as well as *Pinus contorta, Pinus monticola,* and *Pinus ponderosa* on some sites) invade along with *Abies grandis.* By the time a pole-sized stand has developed, *Abies grandis* is generally the only species that continues to reproduce beneath the forest canopy.

Undergrowth is characterized by moist-site herbs including *Clintonia, Adenocaulon bicolor, Disporum hookeri, Galium triflorum,* and *Bromus vulgaris* as well as the subshrub *Linnaea borealis.* Several shrubs share dominance in younger stands; these include *Acer glabrum, Rosa gymnocarpa, Rubus parviflorus, Amelanchier alnifolia, Spiraea betulifolia,* and *Symphoricarpos albus* (appendix C). A number of these species are part of the "*Pachistima* union" described by R. and J. Daubenmire (1968) for northern Idaho. However, the "*Pachistima* union" nomenclature was not used in this classification because individual members of the union have different range limits eastward from Idaho. *Clintonia uniflora* is a reliable indicator species for moist sites within the *Abies grandis* series, and also has high fidelity in the *Abies grandis/Pachistima myrsinites* h.t. of northern Idaho; thus, the latter is similar to our *ABGR/CLUN* h.t.

Clintonia uniflora (CLUN) phase.--This is the typical and most extensive phase, generally occurring at elevations below 4,500 feet. In the wettest mountain ranges it occurs on dry exposures, with adjacent moist sites being occupied by the *THPL/CLUN* or *TSHE/CLUN* h.t.s. In drier areas it typically occurs on moist exposures, with adjacent drier sites being occupied by the *PSME/PHMA* or *ABGR/LIBO* h.t.s. Cooler sites usually support the *XETE* phase of *ABGR/CLUN* h.t. or the *ABLA/CLUN* h.t.

Aralia nudicaulis (ARNU) phase.--This phase was sampled on low elevation (near 3,000 feet) bottomlands and moist benches in northwestern Montana. *Picea* and *Betula papyrifera* are more common here than in other phases, while *Pinus contorta* and *Abies lasiocarpa* are usually absent. Undergrowth is more luxuriant than in other phases, with *Aralia* and *Disporum hookeri* usually well represented. This phase was also found in similarly wet sites (at 4,000 to 4,500 feet in the Bitterroot Range south of Missoula, where it was indicated by *Athyrium filix-femina* being common.

Xerophyllum tenax (XETE) phase.--This phase was encountered at somewhat higher elevations (3,600 to 5,000 feet), where it occupies relatively cold and well-drained sites within the habitat type. It appears to be environmentally intermediate between the warmer *CLUN* phase and the colder *Abies lasiocarpa* series. *A. lasiocarpa* is more common in this phase, while *Pinus ponderosa* is usually absent. *Xerophyllum* and *Vaccinium* globulare are well represented.

Although it occupies a limited area in Montana, the XETE phase is common in the Selway River drainage of Idaho (Habeck 1973, 1976; Robert Steele and others 1976 preliminary draft, USDA Forest Service, Intermountain Station).

Soil/Climate.--The *ABGR/CLUN* h.t. was sampled on a variety of noncalcareous substrates (appendix D-1). Surface soils were gravelly sandy loams to silts in the *CLUN* phase, gravelly loams in the *XETE* phase, and usually, nongravelly silt loams and silts in the *ARNU* phase. Reactions ranged from acidic to slightly acidic in all phases. Little surface rock or bare soil were exposed; duff depths were moderate (3 to 6 cm).

Weather data from Trout Creek, Montana, (appendix D-2) represent the climate of a warm site at low elevation in this habitat type.

Productivity/Management.--*ABGR/CLUN* has high to very high timber productivity (appendix E-3). Partial cutting practices will lead to dominance by *Abies grandis*, which is often greatly reduced in value by Indian paint fungus *(Echinodontium tinctorum)*. Obtaining regeneration of the seral species is usually the best approach for timber management.

Abundant forage for deer and elk is produced during earlier successional stages. Although many stands showed evidence of browsing, the low-elevation and south-exposure sites are usually the only portions of the habitat type offering winter-range potential. Domestic forage production is minimal in natural stands.

Other studies.--The *CLUN* phase is comparable to most of the stands in R. and J. Daubenmire's (1968) *Abies grandis/Pachistima* h.t. in northern Idaho.

Abies grandis/Linnaea borealis h.t.
(*ABGR/LIBO*; grand fir/twinflower)

Distribution.--*ABGR/LIBO* is a minor habitat type in Montana that occurs between about 3,700 and 5,500 feet on northerly to southeasterly aspects. It is locally common in the mountains near Perma and Hot Springs, as well as at various locations in the Bitterroot Range south of Missoula. It often occupies better-drained slopes or benches adjacent to the *ABGR/CLUN* h.t. on moist sites, such as ravines. As one moves east or south, out of the maritime-influence climatic zone, this habitat type replaces *ABGR/CLUN*.

Vegetation.--Most sample stands are dominated by *Pseudotsuga, Larix occidentalis,* or *Pinus ponderosa,* with *Abies grandis* gaining dominance in the understory. In contrast to other habitat types in the series, *Abies lasiocarpa* and *Picea* were absent from almost all stands.

Undergrowth is similar to that of the *ABGR/CLUN* h.t. except for the lack of certain "*Pachistima* union" members (such as *Clintonia, Adenocaulon bicolor*, and *Disporum hookeri*) and the scarcity of others (such as *Galium triflorum*). *Linnaea* often forms a rather extensive mat on the forest floor.

Linnaea borealis (LIBO) phase.--This appears to be the most common phase, ranging from 3,700 to above 4,600 feet on northerly aspects. *Pinus ponderosa* is often a major seral dominant.

Xerophyllum tenax (XETE) phase.--Stands observed in this phase occur between 4,700 and 5,500 feet on easterly to southeasterly exposures. It appears to be transitional between the *LIBO* phase and the *ABLA/LIBO* h.t., *XETE* phase or the *ABGR/XETE* h.t.

Soil.--Our two stands having soils data were on noncalcareous parent materials (appendix D-1). Surface soils were acidic, gravelly loams to silts. Ground surfaces had no rock or bare soil exposed; duff depths were 3 and 4 cm.

Management Implications.--Timber productivity is high (appendix E-3) affording good opportunities for timber management. Productivity was highest in the *LIBO* phase. Forage production for deer and elk is moderately good in early successional stages, although sites are often not accessible for winter range. Forage production for domestic livestock offers little potential.

Other studies.--This habitat type has been described by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) in central Idaho as well as by Robert Steele and others (1976 preliminary draft, USDA Forest Service, Intermountain Station) for the Nezperce National Forest.

Abies grandis/Xerophyllum tenax h.t.
(*ABGR/XETE*; grand fir/beargrass)

Distribution.--*ABGR/XETE* is a minor habitat type locally common on well-drained slopes between 4,700 and 5,300 feet in western portions of the Lolo and Bitterroot National Forests. It is apparently the driest of the *Abies grandis* habitat types in Montana, being bordered on more moist sites by the *ABGR/CLUN* or *ABGR/LIBO* h.t.s and on colder sites by *ABLA/XETE*.

Vegetation.--Most sample stands were rather young (50 to 100 years) and were dominated by *Pseudotsuga, Larix,* and *Pinus contorta*. Regeneration of *Abies grandis* was abundant in some stands, but was scattered in other stands apparently because of difficulties in establishment (dry site conditions). We interpret *Abies grandis* as a significant site indicator and predict that it will be a major component, if not dominant, in climax stands.

Undergrowth is rather sparse, with only *Xerophyllum, Vaccinium globulare, Calamagrostis rubescens*, and sometimes *Pachistima* or *Arnica latifolia* being well represented. Moist site species such as *Clintonia, Linnaea, Adenocaulon*, and *Galium triflorum* are absent.

Soil.--Field observations indicated that soils were similar to those in the *ABGR/CLUN* h.t. Ground surfaces had little bare soil and surface rock exposed; duff depth ranged from 1 to 3 cm.

Productivity/Management.--Timber productivity is moderate to high (appendix E-3). Numerous valuable seral species and ease of regeneration are favorable for intensive timber management; however, the type only covers a small area. Forage production for deer and elk is good, although primarily for spring through fall use. According to Richard Ringleb (Lolo National Forest, Missoula) young stands originating after the 1910 burn in the St. Regis River Valley are used heavily by deer and elk, with major browsing on *Vaccinium globulare* and *Pachistima*. *ABGR/XETE* provides no potential for domestic livestock use.

Other studies.--Habeck (1973, 1976) and Robert Steele and others (1976 preliminary draft, USDA Forest Service, Intermountain Station) have identified an *ABGR/XETE* h.t. as representing sites at the cold, dry limits of the *Abies grandis* series in the Selway River drainage in Idaho. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have described an *Abies grandis/Vaccinium globulare* h.t. in central Idaho, that may represent an extension of *ABGR/XETE* beyond the geographic range of *Xerophyllum tenax*.

Thuja plicata Series and *Tsuga heterophylla* Series

Distribution.--Associations dominated by *Thuja plicata* and *Tsuga heterophylla* occupy moist areas within the maritime-influenced climatic zone of the northern Rocky Mountains. They occur extensively in northern Idaho (R. and J. Daubenmire 1968), but diminish eastward in northwestern Montana. In Montana these habitats are generally confined to bottomland or northerly exposures between about 2,000 and 5,000 feet elevation on sites where average annual precipitation is 32 inches or more. They are bordered on drier sites by the *Abies grandis* series and on colder sites (at higher elevations and in frost pockets) by the *Abies lasiocarpa* series (*ABLA/CLUN* h.t.).

Both the *Thuja* and *Tsuga* series are most common in the extreme northwestern portion of Montana but extend eastward sporadically almost to the Continental Divide in Glacier National Park. Isolated stands of the *Tsuga* series also occur locally in the Swan Valley, but generally *Tsuga* is confined to the vicinities of Libby and Thompson Falls and westward to Idaho. The *Thuja* series occurs more extensively in the Swan Valley and Mission Range; it extends eastward locally to Missoula, and forms small riparian stringers along major streams in the Bitterroot Range west of Hamilton.

Vegetation.--*Thuja* and *Tsuga* are shade-tolerant climax conifers that grow in similar environments. However, *Thuja* extends locally onto slightly drier sites than *Tsuga*, in addition to spreading farther south and east in Montana. *Tsuga heterophylla* is usually capable of attaining dominance over *Thuja* and other species at climax because it is better able to reproduce under a dense forest canopy. However, *Thuja* is capable of maintaining itself indefinitely as a minor climax species in the *Tsuga* series because of its shade tolerance, longevity (often 600 to 1,000 years), and apparent ability to regenerate vegetatively (Habeck 1968).

There are two exceptions to the climax dominance of *Tsuga*. One is the high water table *Thuja/Oplopanax* h.t. where *Thuja* and *Tsuga* are considered as major coclimax dominants in Montana (appendix B). The other exception occurs sometimes near the range limits of *Tsuga* in Montana, where only scattered individuals of *Tsuga* are present (often exhibiting frost-killed tops) in stands having *Abies lasiocarpa* clearly indicated as the potential climax dominant.

Pseudotsuga, Larix occidentalis, and to a lesser extent *Picea* are often dominants in seral stands in these series (appendix B). *Pinus contorta, Pinus monticola,* and *Betula papyrifera* are minor components of seral stands. *Abies grandis* and *A. lasiocarpa* are either minor seral or minor climax components of most of the habitat types. *Thuja* and *Tsuga* usually regenerate on disturbed sites along with and beneath the seral tree species, but it takes them several hundred years to assume dominance in the overstory because of the longevity of the large seral trees. Stands commonly have a mixture of four to six tree species; occasionally as many as 10 tree species can be found in the same stand.

Undergrowth is composed of many moist-site forbs and shrubs (appendix C-1 and C-2); coverages vary considerably depending upon successional status. In the most dense forest stands, *Clintonia uniflora* persists as a useful indicator of the "*Pachistima union*" described by R. and J. Daubenmire (1968).

Early successional stages may be dominated by a dense invasion of *Epilobium angustifolium* and other forbs, or shrubfields composed of *Salix scouleriana, Rubus parviflorus, Amelanchier alnifolia, Acer glabrum, Vaccinium globulare, Ceanothus velutinus,* and (near the Idaho-Montana border) *Ceanothus sanguineus.*

Soil/Climate.--Parent materials within both series are exclusively noncalcareous and nonigneous--predominantly sedimentary rock and argillite (appendix D-1). Presumably, volcanic ash and loess deposits have also had a major influence on soil development with resultant fertility and moisture-holding characteristics beneficial to *Thuja, Tsuga,* and associated undergrowth. Surface soils are primarily acidic, gravelly loams to silts. Ground surfaces rarely have exposed rock or bare soil; mean litter depth exceeds 5 cm for all habitat types and phases in the series.

Weather records from Heron, Montana, near the Idaho border (appendix D-2), illustrate the moist, mild-temperature conditions associated with these series. R. and J. Daubenmire (1968) presented additional climatic data for sites in northern Idaho.

Productivity/Management.--The *Thuja* and *Tsuga* series have the highest timber productivity (appendix E-3). Maximum production is usually found in stands dominated by seral species. Shade-tolerant conifers are often susceptible to fungal decay (e.g., *Echinodontium tinctorum* in *Abies grandis* and *Tsuga*) that may be accelerated by partial cutting. Maximum productivity will likely be realized by even-aged management of seral species. Natural regeneration occurs readily when an adequate seed source is available and site preparation has been thorough enough to retard development of brushfields.

Forage potential (primarily palatable shrubs) for deer and elk is very high in early successional stages, but may be almost nonexistent in dense, near-climax stands. In some areas, these series occur at low enough elevations to provide winter range. *Thuja plicata* may be utilized heavily on big-game winter range. Forage potential for domestic livestock is very low.

Other studies.--Our habitat types within the *Thuja* and *Tsuga* series are essentially equivalent to those defined for northern Idaho by R. and J. Daubenmire (1968). However, we used the typal epithet of--/*Clintonia uniflora* instead of--/*Pachistima myrsinites* to maintain consistency with related habitat types in the *Picea, Abies grandis,* and *Abies lasiocarpa* series

Thuja plicata/Clintonia uniflora h.t.
(*THPL/CLUN*; western redcedar/queencup beadlily)

Distribution.--*THPL/CLUN* is relatively common in northwestern Montana, extending east to Glacier National Park, the Swan River Valley, and south to the Bitterroot

Range near Hamilton. It is typically associated with bottomlands, benches, and northerly exposures from about 2,000 to 5,000 feet in elevation. Within the geographic range of *Tsuga heterophylla* (and therefore the *TSHE/CLUN* h.t.), *THPL/CLUN* is restricted to relatively warmer and drier sites. Beyond the range of *Tsuga*, *THPL/CLUN* occupies the bottoms and extends in fingers up cool and moist ravines bordered by the *ABGR/CLUN* h.t.

Vegetation.--*Thuja* is the indicated climax as well as being the major dominant in most sample stands. Major components of seral stands throughout the habitat type are *Abies grandis*, *Pseudotsuga*, *Larix*, *Picea*, and *Abies lasiocarpa*. *Abies grandis* is usually a persistent seral component, as was found by R. and J. Daubenmire (1968), but occasionally appears to achieve coclimax status with *Thuja*, especially near *Thuja's* range limits in Montana. This situation was found to be common in Idaho's upper Selway River drainage (Habeck 1976).

Clintonia is almost always present in the undergrowth. Other species generally found throughout this habitat type in Montana include shrubs *Rubus parviflorus*, *Vaccinium globulare*, and *Linnaea borealis*, and forbs *Goodyera oblongifolia*, *Pyrola secunda*, and *Viola orbiculata* (appendix C). *Cornus canadensis*, *Adenocaulon bicolor*, *Galium triflorum*, and *Tiarella trifoliata* occur less frequently, but are generally indicative of this habitat type.

Clintonia uniflora (CLUN) phase.--This is the most common phase of the type, and it occurs widely on well-drained bottoms, moist benches, and north slopes. *Menziesia ferruginea*, *Aralia nudicaulis*, and fern indicators of the other phases are notably scarce

Aralia nudicaulis (ARNU) phase.--Undergrowth is distinguished by having *Aralia*, or ferns *Athyrium filix-femina* or *Gymnocarpium dryopteris* common in addition to the usual *Clintonia* associates. This phase also has a more luxuriant assemblage of moist-site forbs, including higher coverages of *Adenocaulon*, *Tiarella*, and *Galium triflorum*. This phase occupies more moist bottoms and slopes than the *CLUN* phase, generally at elevations below 4,000 feet.

Menziesia ferruginea (MEFE) phase.--This phase occurs near the upper elevational (col limits of the habitat type on north-facing slopes or in ravines. It was sampled between 4,300 and 5,300 feet in northwestern Montana. It is identified by *Menziesia* being common in the undergrowth. *Xerophyllum*, *Taxus*, and *Arnica latifolia* are usually conspicuous also, in contrast to the other phases of the habitat type. *Abies lasiocarpa* is almost as abundant as *Thuja* in most stands, and probably plays a minor climax role, although *Thuja* regenerates more effectively. *Larix*, *Pseudotsuga*, and *Picea engelmannii* are the other major constituents of seral stands. *Pinus contorta* is a more frequent seral component in this phase than in other phases of the type, while *Abies grandis* occurs only rarely. This phase is bordered above by *ABLA/CLUN* h.t., *MEFE* phase, or by *ABLA/MEFE* h.t.

Soil.--The *THPL/CLUN* h.t. was commonly found on argillite or noncalcareous sedimentary parent materials (appendix D-1). Surface soils were acidic, gravelly loams to silts Ground surfaces had little rock or bare soil exposed; and duff depths averaged greater than 5 cm.

Productivity/Management.--Timber productivity is high to very high (appendix E-3). However, it is difficult to find free-growing individuals for determining site index in the dense mature stands on this habitat type. Limited data from the *CLUN* phase suggest that productivity is uniformly high for *Pseudotsuga*, *Abies lasiocarpa*, *A. grandis*, *Picea*, and *Larix*. In the *MEFE* phase, productivity is somewhat lower and *A. grandis* is absent. The *ARNU* phase has the highest productivity, especially for *Pseudotsuga* and *Abies grandis*. Although potential productivity is high, realization of it may require intensive management--selecting the best species, controlling the stocking, and minimizing disease and insect losses.

Basal areas are high in stands throughout this habitat type, natural fire frequency is low, although fires that do occur are often intense. Fires early in this century destroyed essentially all *Thuja* in some narrow canyon habitats observed west of Superior, Montana, and *Thuja* has not become reestablished in the new stands. Grazing of *Thuja* by cattle and big game appears to retard natural reinvasion.

Forage production for elk and deer is generally high during early successional stages. Some lower elevation sites provide winter range, with resultant heavy browsing of *Thuja*. Forage potential for domestic livestock is low in natural stands.

Isolated, ancient *Thuja* groves have special appeal for recreation and for botanical studies.

Construction and maintenance of campgrounds, roads, and trails may be difficult and may damage sites in the *ARNU* phase, which has high water tables for at least part of the growing season.

Other studies.--*THPL/CLUN* is very similar to the *Thuja/Pachistima* h.t. described in northern Idaho by R. and J. Daubenmire (1968). Our *CLUN* phase is comparable to most of their habitat type except for four of their stands (numbers 23, 49, 117, and 170), which appear to be similar to our *ARNU* phase. Additionally, our *THPL/CLUN* h.t. in Montana includes a *MEFE* phase which is not comparable to any of R. and J. Daubenmire's northern Idaho stands. Bell (1965) denoted *Aralia* and *Gymnocarpium* as indicators of a major association in the *Tsuga* and *Thuja* forests of interior British Columbia.

Thuja plicata/Oplopanax horridum h.t.
(*THPL/OPHO*; western redcedar/devil's club)

Distribution.--This minor, topo-edaphic habitat type was found only in wet bottoms and toe-slope seepage areas in northwestern Montana. It is usually confined to such sites below about 4,200 feet; at higher elevations the *ABLA/OPHO* h.t. occupies similar sites. Adjacent upland sites support the *TSHE/CLUN* h.t.

Vegetation.--*THPL/OPHO* usually supports ancient stands of large trees with diverse and luxuriant undergrowth. *Thuja* and/or *Tsuga heterophylla* are the climax dominants (fig. 29). Although *Tsuga* was slightly more dominant in most of the 11 Montana sample stands, *Thuja* is also clearly a major climax component in most stands. Since coclimax rather than monospecific dominance is apparently the case, we decided to adopt R. and J. Daubenmire's (1968) "*Thuja/Oplopanax*" terminology for the Montana version of this habitat type. Four of their sample stands from Montana were included in our analyses. See pages 35 and 36 in R. and J. Daubenmire (1968) for a detailed discussion of this habitat type.

Small amounts of *Pseudotsuga, Picea,* and *Abies lasiocarpa* are found in most stands. The latter functions as a minor climax species near the cold limits of the habitat type. Fire seldom destroys these wet-site stands; thus, the trees often attain large size and great age.

Undergrowth is dominated by *Oplopanax, Athyrium,* and *Gymnocarpium dryopteris* superimposed upon the luxuriant forb growth associated with *Clintonia uniflora*. Most prominant of these forbs are *Tiarella trifoliata, Smilacina stellata, Galium triflorum,* and *Adenocaulon bicolor*. *Taxus brevifolia,* a major dominant in the *ABLA/OPHO* h.t., is only a minor constitutent of *THPL/OPHO* stands.

Soil.--Soils data were very limited for this habitat type since most of the sample stands were obtained from other studies. In the two stands we sampled, surface soils were acidic, nongravelly loams (appendix D-1). Ground surfaces had no bare soil or rock exposed. R. and J. Daubenmire (1968) indicated that pH was within the range of the *Tsuga/Pachistima* h.t. (*TSHE/CLUN* h.t. equivalent for Montana).

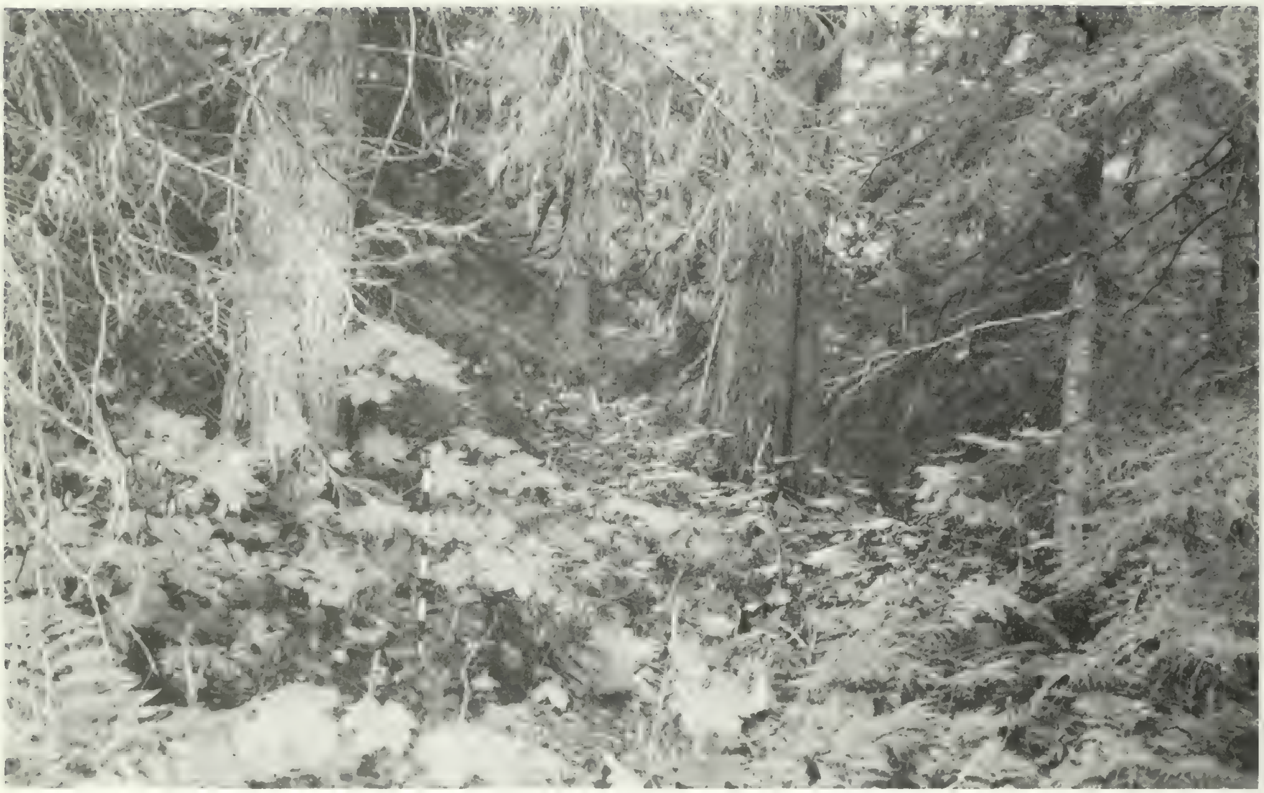


Figure 29.--Thuja plicata/Oplopanax horridum *h.t. on a seep-covered north slope south of Libby in northwestern Montana. This site, at 4,300 feet in elev. has no* Thuja, *and is dominated by* Tsuga heterophylla *with small amount of* Abies lasiocarpa.

Productivity/Management.--Limited site-index data and ecological comparison with the *ABLA/OPHO* h.t. suggest that productivity potential would be high. However, intensive timber management is usually not practiced in this habitat type for several reasons. The habitat type covers a very small area, and existing stands are frequently ancient groves with high recreational, esthetic, and botanical value. Vegetation manipulation would require special constraints in typical streamside locations. High water tables during most of the season and the possibility of compaction preclude use of heavy equipment. Road construction and intensive site development would be expensive, and could cause irreparable damage.

Forage production for deer and elk is low to moderate in typical old-growth stands. Some stands may be valuable for winter range. Forage potential for domestic livestock is very low.

Other studies.--In addition to the similar habitat type described by R. and J. Daubenmire (1968), Bell (1965) recognized comparable associations in the *Tsuga-Thuja* forest of interior British Columbia.

Tsuga heterophylla/Clintonia uniflora h.t.
(*TSHE/CLUN*; western hemlock/queencup beadlily)

Distribution.--*TSHE/CLUN* is restricted to the extreme northwestern portion of Montana (The Libby-Thompson Falls area), with minor extensions east to Glacier National Park. It occupies areas having a very moist, ocean-influenced climate, ranging from the lowest elevations in the State (1,822 feet along the Kootenai River) up to about

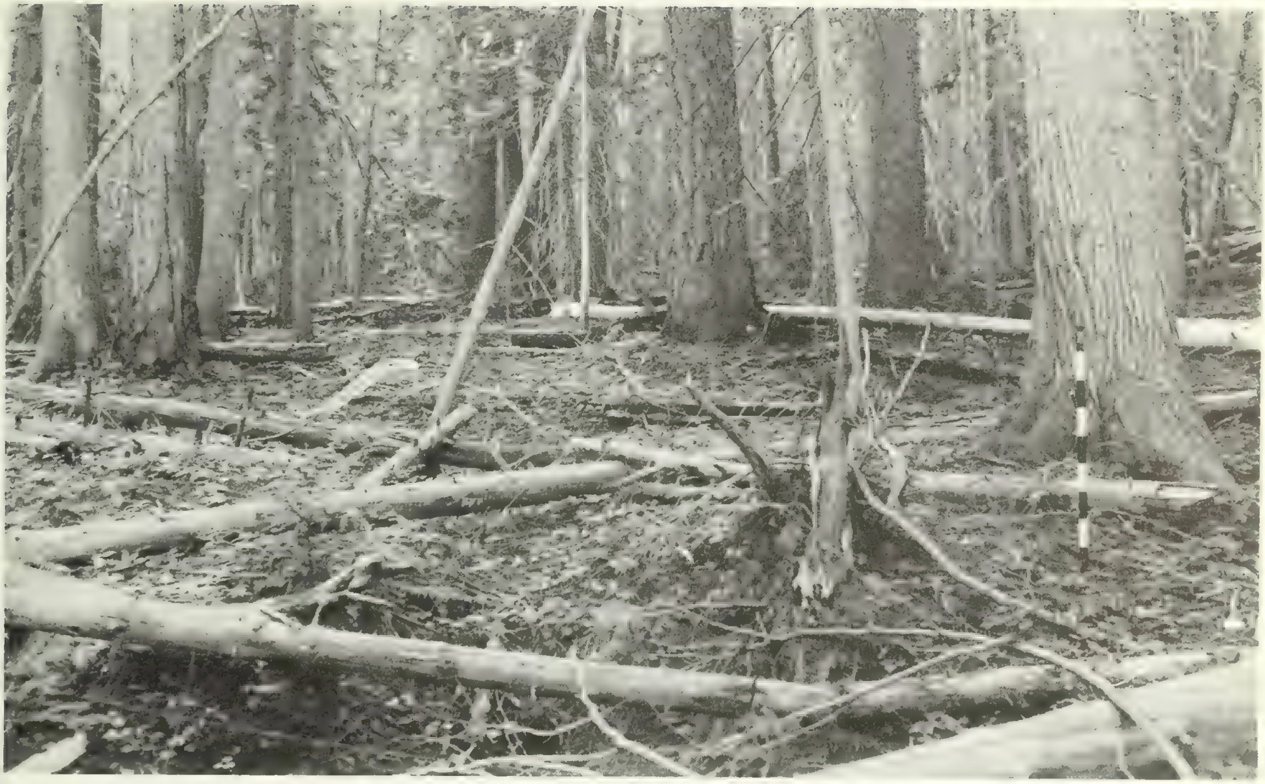


Figure 30.--Tsuga heterophylla/Clintonia uniflora *h.t.* (Clintonia *phase) on a gentle east exposure south of Libby in northwestern Montana. The stand contains the following trees (in decreasing order of abundance):* Thuja, Tsuga heterophylla, Pinus monticola, Abies grandis, Larix occidentalis, Pseudotsuga, Picea, *and* Pinus contorta.

4,000 feet. Sites are mostly in valley bottoms, on benches, or on cool exposures. The eastern outlier of this type in Glacier National Park is apparently dependent upon the moderating climatic influence of Lake McDonald.

Vegetation.--Old-growth stands are usually dominated jointly by *Tsuga* and *Thuja.* Younger stands typically have a diverse mixture of six to nine coniferous species, varying by phase of the habitat type (fig. 30).

Undergrowth throughout the habitat type is characterized by forbs *Clintonia, Pyrola secunda, Tiarella trifoliata,* and *Viola orbiculata,* and shrubs *Linnaea borealis, Pachistima myrsinites, Taxus brevifolia,* and *Vaccinium globulare.*

Density of undergrowth in the *TSHE/CLUN* h.t. is markedly influenced by the development of the overstory canopy. Following destruction of the overstory (e.g., through clearcutting or fire), early successional stages may be brushfields. As a canopy of seral trees develops, the undergrowth density will gradually be reduced. When succession progresses to the point where shade-tolerant trees become dominant in the canopy, shading can eliminate many species and reduce coverage of even the most persistent forbs to just a trace.

Clintonia uniflora (CLUN) phase.--This is the prevalent phase of the habitat type in Montana; it is found on better drained sites. *Larix occidentalis, Pseudotsuga, Pinus monticola,* and *Pinus contorta* have greater representation in this phase than in the others; even *Pinus ponderosa* is occasionally found. Undergrowth has much more *Vaccinium globulare* and *Linnaea borealis* than in the *ARNU* phase.

A few old-growth stands in the *CLUN* phase, mostly on southerly aspects, had *Xerophyllum tenax* well represented in the undergrowth. But the limited extent of these stands and the minor site differences did not seem to warrant recognition of an additional phase.

Aralia nudicaulis (ARNU) phase.--This phase is associated with wetter sites, generally bottoms; *Aralia, Athyrium filix-femina,* or *Gymnocarpium dryopteris* are common and are indicative. *Rubus parviflorus, Adenocaulon bicolor,* and *Tiarella trifoliata* are more abundant than in the *Clintonia* phase.

Soil/Climate.--The *TSHE/CLUN* h.t. occurred almost exclusively on noncalcareous sedimentary and metamorphic parent materials (appendix D-1). Surface soils were acidic gravelly loams to silts. Ground surfaces had virtually no rock or bare soil exposed; duff depth ranged from 4 to 7 cm. Weather data from Heron, Montana, (appendix D-2) represent a relatively warm site within this habitat type.

Productivity/Management.--Timber productivity is high to very high, although it was difficult to find free-growing, vigorous trees of seral species in the old-growth stands sampled. Site-indexes for *Larix* and *Picea* are some of the highest attained for these species (appendix E). Because of moderate terrain, accessibility, and high productivity, *TSHE/CLUN* sites are excellent candidates for intensive timber management. Realizing this high productivity potential will require selecting the best species, controlling stocking, and minimizing disease and insect losses. Obtaining natural regeneration on burned or scarified clearcuts of moderate size is usually no problem, except when brushfields temporarily dominate early succession. Planting and direct seeding have a high probability of success; these measures are sometimes necessary to control species composition or to compensate for lack of a natural seed source.

Forage production for elk and deer is very high during early successional stages, and almost nonexistent, except for *Thuja* saplings, in dense, near-climax stands. Lower elevation sites often provide winter range for big game, with resultant heavy browsing of *Thuja*. Forage potential for domestic livestock is very low.

Isolated ancient groves of *Tsuga* and *Thuja* have high recreational and botanical value.

Intensive development may be difficult and may damage the site in the *Aralia* phase, which has a high water table for at least part of the growing season.

Other studies.--It is evident from the species composition that *TSHE/CLUN* is essentially equivalent to the *Tsuga/Pachistima* h.t. described for northern Idaho by R. and J. Daubenmire (1968). Concerning our *ARNU* phase, Bell (1965) also used *Aralia* and *Gymnocarpium* to designate an association within the *Tsuga* and *Thuja* forests of interior British Columbia.

Abies lasiocarpa Series

Distribution.--The *Abies lasiocarpa* series includes all forests potentially dominated at climax by *Abies lasiocarpa, Tsuga mertensiana, Pinus albicaulis,* or *Larix lyallii*. As indicated in figure 4, this is the predominant series at higher elevations in the Montana Rockies. At lower elevations in northwestern Montana and in northern Idaho, it often borders moist forests where shade-tolerant *Abies grandis, Thuja plicata,* or *Tsuga heterophylla* are the indicated climax (fig. 6). Elsewhere in Montana its lower limits are generally reached where slopes are not moist or cool enough to support *Abies lasiocarpa*, and it gives way to the *Picea* or *Pseudotsuga* series. The *Abies lasiocarpa* series is much more extensive and diverse eastward in Montana than it is in northern Idaho because of more abundant high-elevation terrain as well as a climate unfavorable to its potential competitors--*Abies grandis, Thuja,* and *Tsuga heterophylla.*

Near its upper limits this series forms the timberline, which is bordered above by alpine tundra. On especially dry, warm, windy exposures east of the Continental Divide, this series sometimes gives way to subalpine grassland.

The *Abies lasiocarpa* series is subdivided into three elevational categories (fig. 4), reflecting increasingly severe climatic conditions: (1) lower subalpine habitat types; (2) upper subalpine habitat types; and (3) timberline habitat types. This terminology essentially follows that of Weaver and Clements (1938) for western North America as shown graphically by Löve (1970).

Soil/Climate.--Soils in the Abies lasiocarpa series are derived from a variety of parent materials (appendix D-1). Relationships of habitat types to parent materials are not evident except that the *ABLA/CLPS* h.t. is generally restricted to calcareous substrates. Surface soils are usually acidic to very acidic, and range from gravelly sandy loams to silts. Ground surfaces have little rock or bare soil exposed, except in the upper subalpine and timberline habitat types. Duff depth varies; although litter production is relatively low, natural decomposition is slow and reduction of duff by natural fire occurs infrequently.

The progressively colder, shorter growing season at increasing elevations within the *Abies lasiocarpa* series is illustrated in table 5, which gives estimated climatic parameters for the three subdivisions of the series. Data for specific sites are found in appendix D-2.

Fire history.--Lightning-caused wildfires have allowed *Pseudotsuga*, *Larix occidentalis*, and *Pinus contorta* to dominate most stands in the lower subalpine category of the *Abies lasiocarpa* series. Fire is apparently more frequent and less intense in the dry habitat types like *ABLA/VASC* and *ABLA/XETE*, and less frequent and more intense in the moist ones like *ABLA/MEFE*, *ABLA/GATR*, and *ABLA/CLUN*. Although more lightning strikes may occur in the upper subalpine forests, cool, moist conditions and broken, rocky terrain limit the spread of fires. Fires at timberline tend to be even more localized, although they may prevent reestablishment of trees for several decades (Arno 1970).

Table 5.--*Estimated climatic parameters for the three subdivisions of the* Abies lasiocarpa *series in Montana*

Subdivision	July mean temperature	Impact of summer frost	Mean annual precipitation
	Degrees F		*Inches*
Lower subalpine forest	60 to 64	Light to moderate	20 to 50
Upper subalpine forest	55 to 59	Severe	25 to 60
Timberline	50 to 54	Severe	28 to 60
Alpine tundra	≤49		

LOWER SUBALPINE HABITAT TYPES

Distribution.--Lower subalpine habitat types are those generally warm enough to support *Pseudotsuga, Larix occidentalis,* or *Pinus monticola.* This category of habitat types covers about 2,000 feet of elevation on most of the higher mountains in the State. They are even more extensive in the Flathead River drainage of northwestern Montana, where they occupy all but the warmest exposures for about 3,000 feet vertically before giving way to upper subalpine forest at 6,200 to 6,500 feet. On the driest mountains east of the Continental Divide (for example, south of Dillon, Bull Mountain near Whitehall, and the Pryor Mountains), lower subalpine habitat types are largely restricted to a narrow belt on cool exposures.

The majority of sites within the *Abies lasiocarpa* series fall within this lower elevation category, which has 15 habitat types and numerous phases. The *ABLA/CLUN* and *ABLA/MEFE* h.t.s, highly productive for timber and water yields, are extensive in northwestern Montana. The *ABLA/GATR, ABLA/LIBO* and *ABLA/CACA* h.t.s might be considered as their nearest counterparts in productivity south and eastward in Montana, but they are more restricted physiographically to especially moist sites. *ABLA/XETE* is most common on drier uplands west of the Continental Divide, giving way to *ABLA/VASC* and *ABLA/VAGL* on similar upland sites east from the Divide. Dry sites on the east side--especially those on limestone substrates--support *ABLA/ARCO* and *ABLA/CARU*, or *ABLA/CLPS* under extremely droughty conditions.

Vegetation.--*Pseudotsuga* and *Pinus contorta* are major components of seral stands in the lower subalpine category. *Picea* is a major component of the moist habitat types. Our stand table data support the conclusion drawn by R. and J. Daubenmire (1968) that *Picea engelmannii* is generally a long-lived seral species rather than a coclimax in *Abies lasiocarpa* stands. *Larix occidentalis* and locally *Pinus monticola* are major components of stands in northwestern Montana.

Although *Pseudotsuga* is a common seral dominant in the lower subalpine forests, some habitat types or phases in this group contain only accidentals of this species: the *ABLA/CACA* h.t. occurs on sites apparently too wet for *Pseudotsuga* that are commonly bordered, or surrounded, by drier sites where the species is present. The *ABLA/VASC* h.t., *VASC* phase and *THOC* phase have only accidental, stunted individuals of *Pseudotsuga*, but such trees are frequent enough to indicate that these habitats are not clearly beyond the species' cold limits. A few sites in the *ABLA/MEFE* or *TSME/MEFE* h.t.s may not support *Pseudotsuga, Larix occidentalis,* or *Pinus monticola*; but in these cases *Luzula hitchcockii* (and thus *ABLA/LUHI* h.t., *MEFE* phase) serves as an additional indicator of upper subalpine conditions, making it unnecessary to rely solely upon the absence of *Pseudotsuga.*

Productivity/Management.--Timber productivity ranges from low to very high (appendix E). With relatively high precipitation and snowfall (appendix D-2) the lower subalpine sites are also important for water production. Mule deer, elk, and bear use these habitat types for summer range. Domestic stock use is rare west of the Divide, except locally in valley bottom sites. East of the Divide, some of the more moist plateaus and areas of gentle terrain provide moderate grazing opportunities, especially in early successional stages.

UPPER SUBALPINE HABITAT TYPES

Distribution.--This high-elevation forest belt is found all across the Montana Rockies; it covers approximately 700 feet of elevation, and it is bounded above by the timberline habitats. As a rough average this belt extends from 6,500 to 7,200 feet in northwestern Montana, 7,300 to 8,000 feet in west-central Montana, and 8,100 to 8,800 feet in southern Montana.

Vegetation.--Upper subalpine forest habitat types include those above the climatic limits of *Pseudotsuga, Larix occidentalis,* and *Pinus monticola.* Stands from the Continental Divide west characteristically have *Luzula hitchcockii* present in the undergrowth. In addition, except for some northerly exposures in northwestern Montana, stands throughout the State have whitebark pine well represented (canopy coverage greater than 5 percent).

Abies lasiocarpa is the indicated climax, but its growth in these habitats is quite slow, often requiring 200 years to reach dominant stand height (60 to 70 feet). Moreover, since its wood is weak and brittle, susceptible to wind and snow breakage, and to decay, these trees seldom live much more than 250 years.

Pinus albicaulis is often a persistent dominant seral species on all but the moist sites. It is hardier, longer lived (often surviving 500 to 700 years), and more drought-tolerant than *Abies*; it appears to be intermediate in shade tolerance, rather than very intolerant as suggested by Baker (1949). Most of the larger individuals of *Pinus albicaulis* over vast areas of the Northern Rockies were killed between 1909 and 1940 by mountain pine beetle (*Dendroctonus ponderosae*) epidemics (Arno 1970; personal communication with Arthur Roe, Forest Service retiree, Missoula, Montana); nevertheless *Abies* has not been able to substantially replace *Pinus albicaulis* in these habitat types.

Picea is longer-lived than *Abies*, and functions as an important, persistent seral component of stands on moist sites, but only as a minor seral component on dry sites. *Pinus contorta* is a major seral species in the lower portion of the upper subalpine belt.

Productivity/Management.--The upper subalpine forest is highly productive for water yield and constitutes a sizable proportion of the land in Wilderness and back-country recreation areas. It is also important as summer range for mule deer, elk, bears, and other big game species. Domestic forage production is low in these stands. Timber productivity is generally low (appendix E) and management is frequently hampered by problems in road construction, harvesting, regeneration, and site protection.

TIMBERLINE HABITAT TYPES

Distribution.--Timberline habitat types form the transition between contiguous forest and alpine tundra. These habitat types are relatively common in the higher mountain ranges of the State, occurring primarily on rugged topography west of the Continental Divide, but often on relatively broad, gentle slopes east of the Divide. Climatic timberline habitats generally average about 7,200 to 8,000 feet elevation in northwestern, 8,000 to 8,800 feet in west-central, and 8,800 to 9,600 feet in southern Montana. They usually occur somewhat higher on southerly exposures than on north-facing slopes, because of warmer summer temperatures. However, where the extremely cold-tolerant *Larix lyallii* (*LALY/ABLA* h.t.s) occupies north slopes, it may reach elevations comparable to the limits of other species on nearby southern aspects.

Timberline extends upward from the limit of contiguous forest ("forest line") to the general upper limits of krummholz or shrub-like trees ("scrub line") (Arno 1966). In some areas this forest line is hard to determine; a useful alternate indication is that forest line occurs where *Abies lasiocarpa* becomes generally stunted, and is usually not capable of developing as a tall tree (50 feet high) except when growing up through the crown of a *Picea, Pinus albicaulis,* or *Larix lyallii.* Widely scattered krummholz known as "alpine scrub" may occur above timberline in the lower fringes of the alpine tundra (Arno 1966).

Vegetation.--Only four tree species typically inhabit Montana timberlines. These are *Larix lyallii, Pinus albicaulis, Picea engelmannii,* and *Abies lasiocarpa,* listed in order of decreasing vigor or cold tolerance of timberline. *Abies* is noticeably stunted, sometimes shrub-like, or often with shrubby skirts, and it relies to a considerable extent upon vegetative means (i.e., layering of lower branches) for successfull regeneration. Competition related to tolerance is less evident than in lower habitat types, and "climax" relationships are frequently unclear.

At timberline, trees take on several life forms and often grow in groups or clusters with open areas in between. Vegetational communities often form an intricate mosaic. Because of the especially complex and unusual ecological relationships at timberline, the three habitat types in this group were named only for their tree components; this approach was used also by R. and J. Daubenmire (1968).

We recognize that definite combinations of trees and undergrowth species are recognizable at timberline. These have been delineated in detailed studies of timberline environments, as in Arno (1970) and Weaver and Dale (1974). However, in the broader perspective of the entire Montana classification, it seems unwarranted at this time to propose a detailed treatment of the extraordinarily complex differences in tree/undergrowth vegetation in timberline habitats.

Climate.--In general, cold summer temperature appears to be the most critical factor responsible for timberline formation in Montana (table 5); although some limits of the ecologically diverse *PIAL* h.t.s are evidently controlled by other factors. Alpine an Arctic timberlines throughout the Northern Hemisphere have been found to approximately coincide with the 50°F isotherm for the warmest month of the year (usually July) (Arno 1966, 1970). Habitats having a mean July temperature significantly less than 50°F support only tundra.

Such temperature-controlled or "Climatic" timberlines are the ones under general consideration here. Locally, excessive accumulations of snow (especially in northwestern Montana) or extreme rockiness and exposure to desiccating winds may cause an apparent timberline formation at unusually low elevations. However, such plant communities are composed largely of species characteristic of middle or lower elevation forests; thus, these areas are more accurately treated as forest-meadow or forest-grassland ecotones, or snowdrift, wind-funnel, or rock-outcrop sites. In Montana, climatic timberline sites are generally above the cold limits of *Pinus contorta, P. flexilis*, *Pseudotsuga*, *Tsuga mertensiana*, *Menziesia ferruginea*, and *Calamagrostis rubescens*.

Blizzard conditions occur commonly in timberline types in all months except July and August. Even during the brief growing season, winds of gale and hurricane velocity are rather common. In the more moist ranges, snow accumulations may be so great in the *PIAL/ABLA* and *LALY/ABLA* h.t.s that most of the steeper slopes are subject to snowslides or avalanche. Snowdrifts may persist so late into summer during some years that they retard plant growth. Sites with exceptional wind exposure are swept free of snow almost all winter; here, deep soil frost, winter and summer desiccation, extensive temperature fluctuations, and the mechanical damage caused by winds combine to inhibit tree growth.

Productivity/Management.--Timberline habitats have high water yields and provide summer range for various species of big game and other wildlife. Because of their high esthetic value, they are also of considerable interest to outdoor recreationists. Forb and grass growth may be luxuriant in certain timberline areas, particularly those east of the Continental Divide on better soils, notably those derived from limestone. Grazing pressure in these types must be carefully dispersed and otherwise controlled, however, because loss of vegetative cover makes them vulnerable to severe erosion in many cases. Vegetative recovery following disturbance is very slow. Heavy grazing by sheep has caused long-term range deterioration in several timberline and alpine areas in the Northern Rockies, although timberline meadows in Montana generally appear to be in better shape than those in the other Rocky Mountain States.

Similarly, the vegetation can support little concentrated use by sightseers or campers. Roads, ski facilities, and other developments are usually damaging to timberline ecosystems unless designed, constructed, and maintained with utmost care. The scenic beauty of these environments is easily degraded also. Vegetative healing of scarred areas may require several decades, and in some cases the degradation may be permanent (Habeck 1972; Willard and Marr 1971; Klock 1973).

Tree growth and regeneration are extremely slow in these habitat types, which can clearly be considered as "noncommercial" forest land (appendix E).

LOWER SUBALPINE HABITAT TYPES

Abies lasiocarpa/Oplopanax horridum h.t.
(*ABLA/OPHO*; subalpine fir/devil's club)

Distribution.--*ABLA/OPHO* is a rare but very distinctive habitat type found in the Flathead and Kootenai River Drainages of northwestern Montana. It is restricted to ravine bottoms and sites near streams, springs, or seepage areas where the water table remains near the surface all year (fig. 31) Often it develops only as narrow stringers covering no appreciable acreage. Elevations of observed *ABLA/OPHO* sites range from 3,900 to almost 5,000 feet. Sites are similar to those of the *THPL/OPHO* h.t. except that they occur in colder areas.

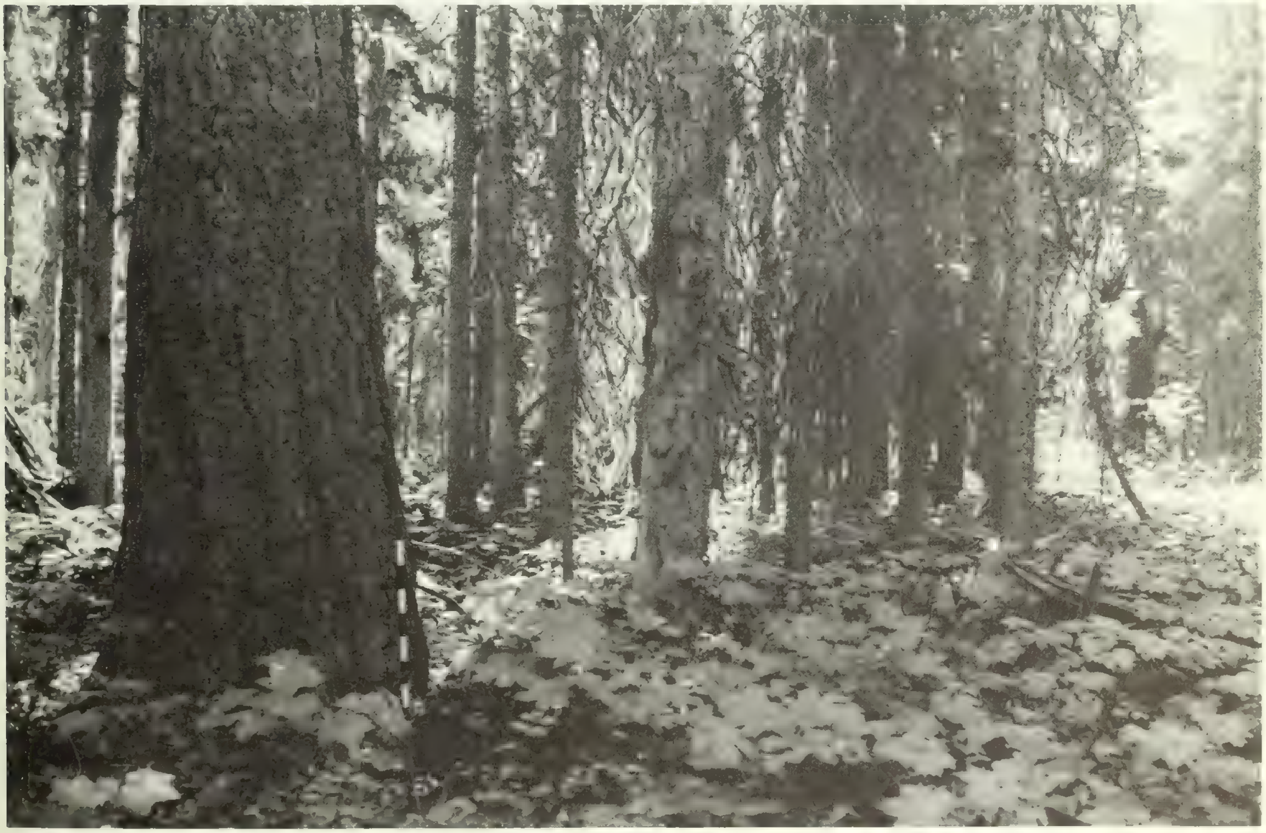


Figure 31.--Abies lasiocarpa/Oplopanax horridum *h.t. on a valley bottom site on the west side of Glacier National Park at 3,900 feet elev.* Abies, Picea, *and a few large* Larix occidentalis *make up the overstory.*

Vegetation.--Old-growth stands are codominated by *Abies lasiocarpa* and *Picea*; the latter will evidently maintain itself as a minor climax component. Small amounts of *Pseudotsuga, Larix occidentalis,* and *Pinus monticola* are found, while *Thuja* and *Tsuga heterophylla* sometimes occur sporadically as accidentals. Fire often skips these wet-site stands; thus they may support groves of old and very large trees (sample stands had trees taller than 150 feet).

Undergrowth is dominated by a shrub layer of *Oplopanax* and *Taxus brevifolia*. Beneath this, forbs *Clintonia uniflora* and *Tiarella trifoliata* and ferns *Athyrium filix-femina* and *Gymnocarpium dryopteris* are usually well represented.

Soil.--Our stands were on a variety of noncalcareous parent materials (appendix D-1). Surface soils were very acidic, nongravelly loams. Ground surfaces were rock free and no bare mineral soil was exposed. Duff depths were among the greatest recorded in any habitat type (7 to 10 cm).

Productivity/Management.--Productivity potential for timber is moderate to high (appendix E), but sites are generally not suitable for intensive timber production. As in the *THPL/OPHO* h.t., this habitat type occupies very small areas, often has high recreational and esthetic values, and has high water tables that preclude use of heavy equipment. Road construction, trails, and site development problems can be minimized by avoiding these sites. Domestic grazing potential is very low and little deer or elk use was observed.

Other studies.--A similar plant association was described by Illingworth and Arlidge (1960) for eastern British Columbia, and by Ogilvie (1962) for southwestern Alberta.

Abies lasiocarpa/Clintonia uniflora h.t.
(*ABLA/CLUN* h.t.; subalpine fir/queencup beadlily)

Distribution.--*ABLA/CLUN* is a relatively moist and warm habitat type for the *Abies lasiocarpa* series (fig. 32). It is extensive in the northwestern portion of the State, especially in the Flathead River drainage. There, it occurs (in five phases) from the lower mountain valleys at about 3,200 feet elevation up to 5,500 feet, and it can be found on all but the driest south-facing slopes. Its abundance and diversity is attested to by the large number (103) of *ABLA/CLUN* h.t. stands sampled in the course of this study.

It is extensive on both slopes of the Continental Divide in Glacier National Park and also immediately south of the Park. Westward, on comparable mountain slopes in the Kootenai River drainage (and in northern Idaho), Pacific maritime conifers (*Tsuga, Thuja*, and *Abies grandis* become increasingly common, and the *ABLA/CLUN* h.t. is more restricted in its distribution. *Clintonia* (necessary for this habitat type) is uncommon south or east of Missoula, and where it does occur it is largely restricted to swales or along streams.

Abies lasiocarpa is the indicated climax throughout the habitat type. Its major associates in seral stands are *Picea engelmannii* (or hybrids with *P. glauca*), *Pseudotsuga*, *Larix occidentalis*, *Pinus contorta*, and *P. monticola*. Additionally, all other tree species native to northwestern Montana with the exception of *Juniperus scopulorum* and *Larix lyallii* are sometimes found as minor stand components.

Diversity of the undergrowth among the five phases of *ABLA/CLUN* is even more marked than that of the tree layer; however, a sizable number of species are found throughout all five phases. *Clintonia uniflora* is indicative of this habitat type. *Adenocaulon bicolor*, *Coptis occidentalis*, *Cornus canadensis*, *Disporum hookeri*, *Galium*

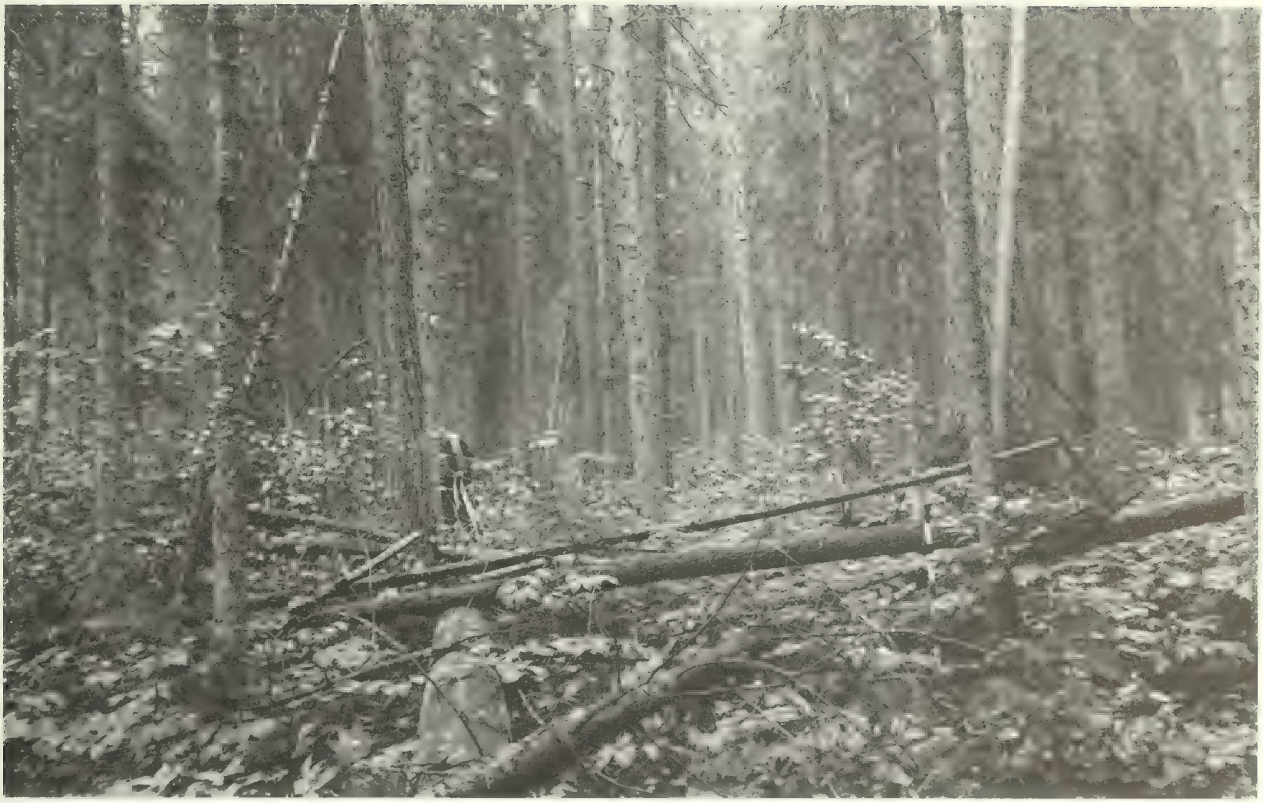


Figure 32.--Abies lasiocarpa/Clintonia uniflora *h.t.* *(*Aralia *phase) on a moist bench (3,900 feet elev.) south of Hungry Horse Reservoir in northwestern Montana. Old-growth* Larix occidentalis *and many-aged* Picea *dominate, with younger* Abies Lasiocarpa *increasing in abundance.* Aralia *is the dominant forb.*

triflorum, and *Tiarella trifoliata* are forbs largely restricted to the *Clintonia* undergrowth types in northwestern Montana. Shrubs *Linnaea borealis, Lonicera utahensis, Pachistima myrsinites,* and *Rubus parviflorus* are characteristically found throughout *ABLA/CLUN* h.t., and *Vaccinium globulare* is usually well represented. Forbs that are rather widespread in other types as well as being present throughout *ABLA/CLUN* include *Arnica latifolia* (usually well represented), *Chimaphila umbellata, Goodyera oblongifolia, Osmorhiza chilensis, Pyrola secunda, Thalictrum occidentale, Viola orbiculata,* and *Xerophyllum tenax.*

Clintonia uniflora (CLUN) phase.--This is the most common phase, representing the "middle ground" or average environmental conditions in the habitat type. It occurs throughout northwestern Montana and is most common between 4,400 and 5,600 feet, extending somewhat lower on frost-pocket sites.

In the more moist areas of northwestern Montana, this phase can be found on all but the driest exposures. In the drier areas and in west-central Montana it is usually confined to especially moist sites, such as canyon bottoms.

Major components of sample stands are *Abies lasiocarpa, Picea, Pseudotsuga, Larix occidentalis,* and *Pinus contorta,* in order of decreasing abundance; other tree species are relatively scarce. Undergrowth is dominated by species described previously for the habitat type.

Aralia nudicaulis (ARNU) phase.--This is the moist and relatively warm phase of th habitat type characteristic of bottomland sites at the lowest elevations. It is found in bottoms and occasionally toe-slope seepage areas between 3,200 and 4,200 feet elevation in the Flathead River drainage, and at 4,500 to 5,000 feet in west-central Montana as well as on the east side of Glacier National Park.

The major overstory species in the 18 sample stands were *Abies lasiocarpa, Picea, Larix occidentalis, Pseudotsuga,* and *Pinus monticola*, in order of decreasing abundance. *Betula papyrifera,* seldom found elsewhere in conifer forest types, was present in almos half of the sample stands. The phase is identified by *Aralia nudicaulis, Gymnocarpium dryopteris,* or *Athyrium filix-femina* being common. Other undergrowth species prevalent in this phase are: *Cornus stolonifera, Taxus brevifolia, Melica subulata, Oryzopsis asperifolia, Adenocaulon bicolor, Cornus canadensis, Lycopodium annotinum,* and *L. complanatum.*

Vaccinium caespitosum (VACA) phase.--This phase includes *ABLA/CLUN* habitats found on relatively dry, low-elevation benchlands. It is a minor but distinctive phase found on well-drained, gravelly benches between about 3,100 and 4,100 feet, mostly in the upper Flathead Valley. These sites may also be frost pockets.

Tree composition of the 100- to 300-year-old stands sampled is quite distinctive, especially for the *ABLA/CLUN* h.t. *Abies lasiocarpa* is obviously subordinate in coverage to both *Pseudotsuga* and *Pinus contorta. Abies* is clearly the potential climax dominant, but succession is relatively slow. Apparent *Picea glauca* X *P. engelmannii* hybrids and *Larix occidentalis* are common minor stand components, and *Pinus ponderosa* is present in almost half of the stands.

Undergrowth also contrasts with that of other phases of the habitat type. *Vaccinium caespitosum* and *Arctostaphylos uva-ursi* are usually well represented. *Linnaea borealis* is a dominant, and is often accompanied by *Xerophyllum tenax. Calamagrostis rubescens* is usually well represented and *Shepherdia canadensis* is present in most stands. *Galium boreale, Campanula rotundifolia,* and *Cornus canadensis* are often present, while *Thalictrum occidentale* and *Tiarella trifoliata* are usually absent (the latter are usually present in other phases of the *ABLA/CLUN* h.t.). There is some question whether most of the vegetational features described here will persist in "climax" stands. Coverage of *Vaccinium caespitosum* and some other species is reduced in undisturbed old-growth stands, but the question of true climax composition in this case seems academic because of the slow rate of succession.

Xerophyllum tenax (XETE) phase.--This phase occupies most of the dry, cold portion of the habitat type. It is found mostly on well-drained sites between 4,200 and 5,600 feet, commonly on south- or west-facing slopes. It occurs frequently on the Flathead and Lolo National Forests.

Abies lasiocarpa and *Pseudotsuga* were major components of the 21 sample stands, followed in order of decreasing abundance by *Picea engelmannii, Larix occidentalis,* and *Pinus contorta.* Other conifers were of minor importance. Undergrowth was dominated by *Xerophyllum* in addition to the species described previously for the habitat type as a whole.

Menziesia ferruginea (MEFE) phase.--This is the relatively cold and moist phase of the *ABLA/CLUN* h.t., and is transitional above to the *ABLA/MEFE* h.t. It is found throughout northwestern Montana between 4,500 and 5,700 feet, mostly on cool exposures. Also, about half of R. and J. Daubenmire's (1968) *Abies lasiocarpa/Pachistima* h.t. stands in northern Idaho seem equivalent to this phase.

Abies lasiocarpa, Picea engelmannii, and *Pseudotsuga* were the major components of sample stands. *Larix occidentalis* and *Pinus contorta* were often minor components. *Menziesia ferruginea* and *Arnica latifolia* were usually abundant in the undergrowth.

Soil/Climate.--Soils in the *ABLA/CLUN* h.t. were derived from a variety of noncalcareous sedimentary and metamorphic parent materials (appendix D-1). Surface soils were moderately gravelly throughout, with the lowest gravel contents in the *ARNU* phase and the highest in the *XETE* phase. Reactions varied from acidic to very acidic. Ground surfaces had virtually no rock or bare soil exposure and duff accumulation varied from moderate to deep. The *VACA* phase had the least duff (mean = 3.7 cm), while the *MEFE* and *ARNU* phases averaged 6.2 and 7.1 cm, respectively.

Weather data from three stations (appendix D-2) reflect the climate of some of the phases of this habitat type.

Productivity/Management.--Timber productivity potential ranges from moderate to very high in western Montana (appendix E-3). Productivity is highest in the *ARNU* phase and lowest in the *VACA* and *XETE* phases. In the few stands slightly east of the Continental Divide in Glacier National Park and the Lewis and Clark National Forest, productivity is low to moderate (appendix E-4). Five important seral species *(Pseudotsuga, Larix occidentalis, Pinus contorta, Picea,* and *Pinus monticola)* provide flexibility for intensive timber management and opportunities for developing mixed species stands. Preferred species vary by phase, as shown in appendix B; silvicultural prescriptions must be tempered by on-site evaluation of existing stands. Except for sites in the *VACA* phase where it occurs naturally, *Pinus ponderosa* is near its cold limits and grows poorly in this habitat type. Partial cutting of mature stands will increase dominance of *Abies lasiocarpa*. Even-aged management offers greater promise for production of seral species.

The *VACA* phase, with flat ground and well-drained soils, can tolerate heavy equipment, recreational use, and site development. The *ARNU* phase also has gentle topography, but soft ground and high water tables during part of the growing season limit certain activities and developments. The *XETE* and *MEFE* phases (and part of the *CLUN* phase) are typically on steeper ground at somewhat higher elevations, but are still relatively accessible with conventional logging techniques.

Site preparation needs will probably be greatest in the *XETE* and *MEFE* phases, but for different reasons. The *XETE* phase is the droughtiest, and site preparation may be needed for prompt seedling establishment. The *MEFE* phase has ample moisture, but brushfield development could be a problem, although in some areas *Menziesia ferruginea* apparently does not reinvade rapidly following disturbance. Additional observations and data are needed to define early successional development in all phases.

All phases can produce large quantities of browse for elk and deer in early successional stages. However, because of snow depths only a few of the lowest elevation sites (generally *VACA* and *ARNU* phases) provide opportunity for winter range.

Watershed management values in this habitat type are high--as they are throughout most of the *Abies lasiocarpa* series--because of high precipitation and snowpack accumulation.

Other studies.--*ABLA/CLUN* is similar to R. and J. Daubenmire's (1968) *Abies lasiocarpa/Pachistima myrsinites* h.t. Most of their stands are assignable to three of the Montana phases: *MEFE, XETE,* and *CLUN*. We did not extend their "*Pachistima* union" nomenclature to our classification because the undergrowth species making up that union reach their range limits independently going eastward into Montana. Also, these species occupy somewhat different sites in Montana; whereas in northern Idaho they apparently have similar environmental tolerances. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) report that *ABLA/CLUN* h.t. extends southward in west-central Idaho to the vicinity of McCall. *Clintonia uniflora* and many of its Montana associates are also components of major forest communities in western Washington and Oregon (Franklin and Dyrness 1973), suggesting that similar associations occur there.

Abies lasiocarpa/Galium triflorum h.t.
(*ABLA/GATR*; subalpine fir/sweetscented bedstraw)

Distribution.--*ABLA/GATR* is the warmest of the moist *Abies lasiocarpa* habitat types in most of the Montana Rockies. It is similar to the *ABLA/CLUN* h.t., but lacks some of the *ABLA/CLUN* moist-site indicators that do not extend eastward into the areas having a more continental climate.

ABLA/GATR occurs on moist bottomlands, benches, northern exposures, and occasionally in seepage areas on southern exposures. Stands are generally between 5,000 and 6,800 feet elevation, except in the vicinity of the Gallatin National Forest where the type is abundant between about 6,300 to 7,700 feet. In relatively dry mountain ranges, the habitat type is restricted to narrow stringers along stream bottoms. Sites with high water tables (surface water during the first part of the growing season) are often transitional to the *ABLA/CACA* h.t., and are classified as the *GATR* phase of the *ABLA/CACA* h.t., giving major emphasis to the dominant edaphic factors.

Vegetation.--*Picea* is usually dominant over *Abies* in all but the oldest stands. In some *Picea*-dominated old-growth stands on lower slopes south of Bozeman, *Abies* reproduction is less abundant than that of *Picea*. These stands are transitional to the *PICEA/GATR* h.t. found at lower elevations, but are nevertheless classified as *ABLA/GATR* h.t. However, in the vast majority of *ABLA/GATR* sites sampled in Montana, stand-structure data indicate that *Abies* is potentially the climax dominant. *Pseudotsuga* and *Pinus contorta* are usually represented in seral communities.

Dominant undergrowth is variable, especially in seral stands; however, certain moist-site species are characteristic. The habitat type is indicated by the presence of *Galium triflorum*, *Actaea rubra* and *Streptopus amplexifolius*. Since small quantities of *Galium* sometimes occur on adjacent drier slopes or on disturbed sites, *Galium* alone is not an adequate indicator. Other species generally restricted to this or other moist types (i.e., *ABLA/CLUN*, *ABLA/CACA*) include *Cornus stolonifera*, *Angelica arguta*, *Pyrola uniflora*, *Saxifraga arguta*, and *Senecio triangularis*.

Soil.--Soils in the *ABLA/GATR* h.t. were derived from almost all available parent materials (appendix D-1). Surface soils were generally acidic nongravelly loams to silts. Ground surfaces had virtually no bare soil or rock exposed, and duff depth averaged 5.9 cm.

Productivity/Management.--Timber productivity ranges from moderate to high west of the Continental Divide, and is moderate eastward (appendix E). Moderate to heavy use (including browsing and bedding) by deer and elk is apparent in most stands. Moose activity is also common especially on valley-bottom sites. In many areas this habitat type provides the best big-game cover available. Browse production is moderate to good, especially in the earlier successional stages. These sites are often used by cattle, primarily for resting or bedding after feeding on nearby meadows or grasslands. This type has high water yield potential, and management activities must be constrained to protect streams.

Other studies.--In a sense *ABLA/GATR* and *ABLA/CLUN* are similar, and would represent R. and J. Daubenmire's (1968) *Abies lasiocarpa/Pachistima* h.t.; however, *ABLA/CLUN* occurs extensively on uplands in the maritime-influence climatic zone, whereas its eastern counterpart *ABLA/GATR* is generally restricted to sites having especially moist soil. Cooper (1975) described a similar association in northwestern Wyoming. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) described an *Abies lasiocarpa/Streptopus amplexifolius* h.t. in central Idaho that is apparently related to our *ABLA/GATR* h.t. and *ABLA/CACA* h.t., *GATR* phase.

Abies lasiocarpa/Vaccinium caespitosum h.t.
(*ABLA/VACA*; subalpine fir/dwarf huckleberry)

Distribution.--*ABLA/VACA* is confined largely to well-drained sites on benchlands and in frosty basins where cold air accumulates. These sites are at moderate elevations for the *Abies lasiocarpa* series--mostly between 6,000 and 7,200 feet in basins near the Continental Divide and in the Little Belt Mountains (fig. 33). It was also found locally at 5,000 feet in a basin west of Kalispell.

Vegetation.--*Pinus contorta* was the sole dominant conifer in nearly all stands sampled, and it was often reproducing better than other conifers. *Abies lasiocarpa* and *Picea* were common in the understory. Most stands were less than 150 years old, however, so actual climax relationships could not be clearly established. *Pinus contorta* could at least be considered the persistent seral dominant of this habitat type.

Undergrowth is a rather dense mat of *Vaccinium caespitosum, Vaccinium scoparium,* and *Calamagrostis rubescens,* often with *Linnaea borealis.*

The retarded tree succession in this habitat type might be due to frequent summer frosts coupled with warm daily maximum temperatures; this combination would damage new growth of most conifers, but not *Pinus contorta* Often, however, *Picea* and *Abies* are able to grow satisfactorily once they become well established; establishment difficulties may include competition from the undergrowth and lack of seed source, as well as

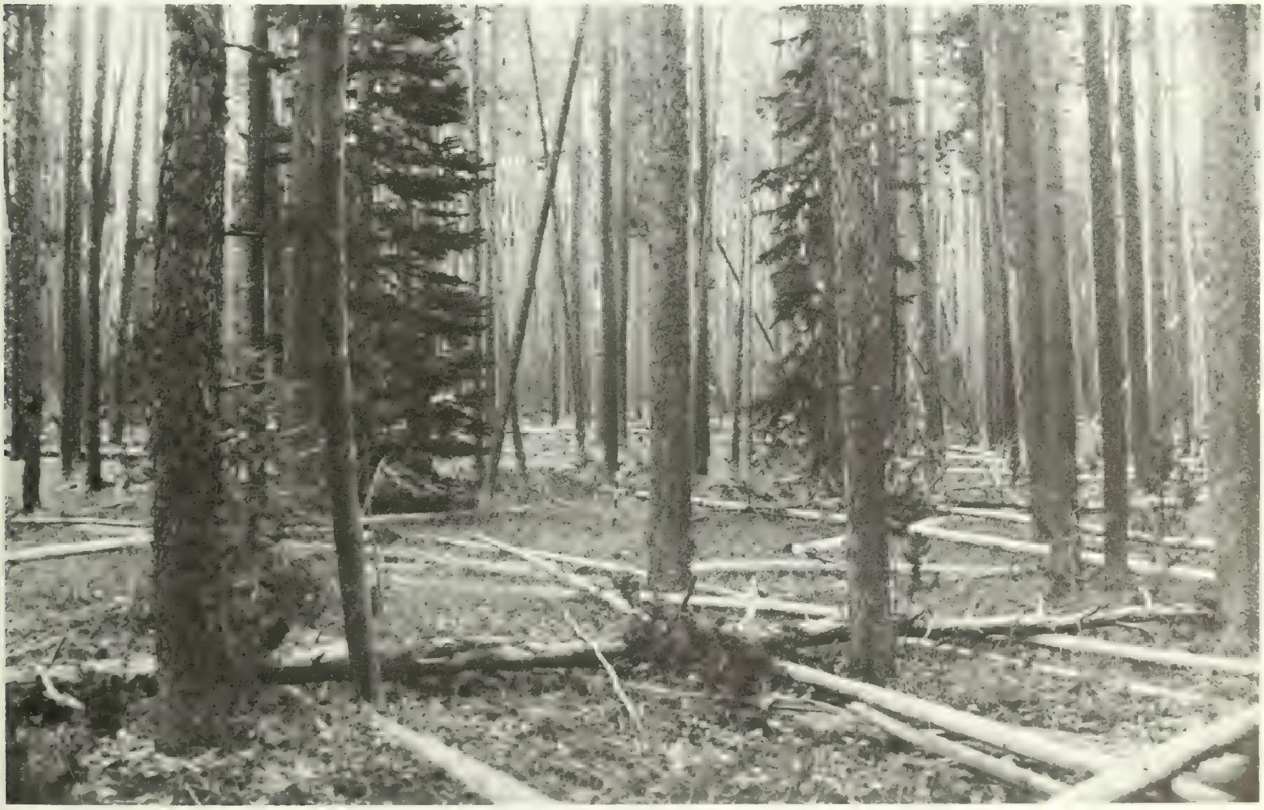


Figure 33.--Abies lasiocarpa/Vaccinium caespitosum *h.t. on benchland (6,400 feet elev.) in the Little Belt Mountains of central Montana.* Pinus contorta *dominates the overstory; regeneration is* P. contorta, Abies lasiocarpa, *and* Pseudotsuga. Calamagrostis rubescens *and* Vaccinium caespitosum *are the principal undergrowth species.*

frost damage. The scarcity of the frost-susceptible *Vaccinium globulare* in this habitat type seems significant also. *ABLA/VASC*, *ABLA/XETE*, or *ABLA/VAGL* is usually found on adjacent upland slopes, and the *ABLA/CACA* h.t., *VACA* phase occurs on adjacent sites with high water tables.

Soil.--Our stands were on a variety of noncalcareous parent materials (appendix D-1). Surface soils were gravelly and nongravelly sandy loams to silts with acidic to very acidic reactions (mean pH 5.0). Ground surfaces had virtually no bare soil or rock exposed; duff depth averaged 4.8 cm.

Productivity/Management.--Timber productivity is moderate (appendix E-4), and *Pinus contorta* appears to be the only species well suited for management. *Pinus contorta* has mostly nonserotinous cones in this habitat type, and natural seedling establishment seems to occur periodically even without disturbance. Gentle terrain and stable soil conditions are favorable for timber management. Some mechanical scarification is desirable to prevent a mat of *Calamagrostis rubescens* from retarding reproduction.

Intensive recreational sites, such as campgrounds and picnic areas, are often located in this habitat type. Observations made in campgrounds indicate that *Vaccinium caespitosum* usually increases its coverage under moderate disturbance, while its associate *V. scoparium* dies out. However, heavy foot traffic, not directed or regulated by paths and barriers, will soon destroy most of the *V. caespitosum* also.

Light to moderate use by moose, elk, and deer is evident. Cattle use also occurs in some areas, although forage potentials for grazing are generally low.

Other studies.--In frosty basins of central Idaho, Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) described an *ABLA/VACA* h.t. dominated by "stable communities of *Pinus contorta*." In most stands they found only scattered and often stunted *Picea* and *Abies* beneath the *Pinus contorta*, along with numerous seedlings of the latter. This situation is more extreme than that found in Montana stands. *ABLA/VACA* has evidently not been described in other areas, although Ogilvie's (1962) *Picea-Abies/Calamagrostis* type appears similar.

Abies lasiocarpa/Calamagrostis canadensis h.t.
(*ABLA/CACA*; subalpine fir/bluejoint)

Distribution.--*ABLA/CACA* is the major forest habitat type on wet sites at relatively high elevations (mostly 6,000 to 7,500 feet in west-central Montana and 7,000 to 8,500 feet east of the Continental Divide) in Montana, except in the northwestern part of the State. It is widely distributed in high mountains near and east of the Continental Divide, but is often confined to small areas because it is restricted to poorly drained sites that have surface water during late spring and early summer (fig. 34). These sites often border streams, adjoin wet meadows (dominated by *Carex* and *Juncus*) supporting only occasional trees, or occur as swales at the drainage headwaters. Adjacent better drained sites often support the *ABLA/VASC* and *ABLA/MEFE* h.t.s. Sometimes *ABLA/CACA* occurs on mountainslope seep areas. Herbert Holdorf (soil scientist, Lewis and Clark National Forest, Great Falls, Montana) has found it to be locally extensive on sites underlain by a clay pan.

Vegetation.--Because of the cool, wet conditions the tree flora is relatively simple. *Picea engelmannii* is usually the dominant species in old-growth stands, and it may persist as a minor climax or coclimax with *Abies lasiocarpa*. *Pinus contorta* is a major seral dominant in many younger stands. The upper limits of the habitat type occasionally extend into the upper subalpine zone in protected basins. *Pinus albicaulis* may be well represented in these situations, but it is most commonly found on hummocks or drier sites within the stand.

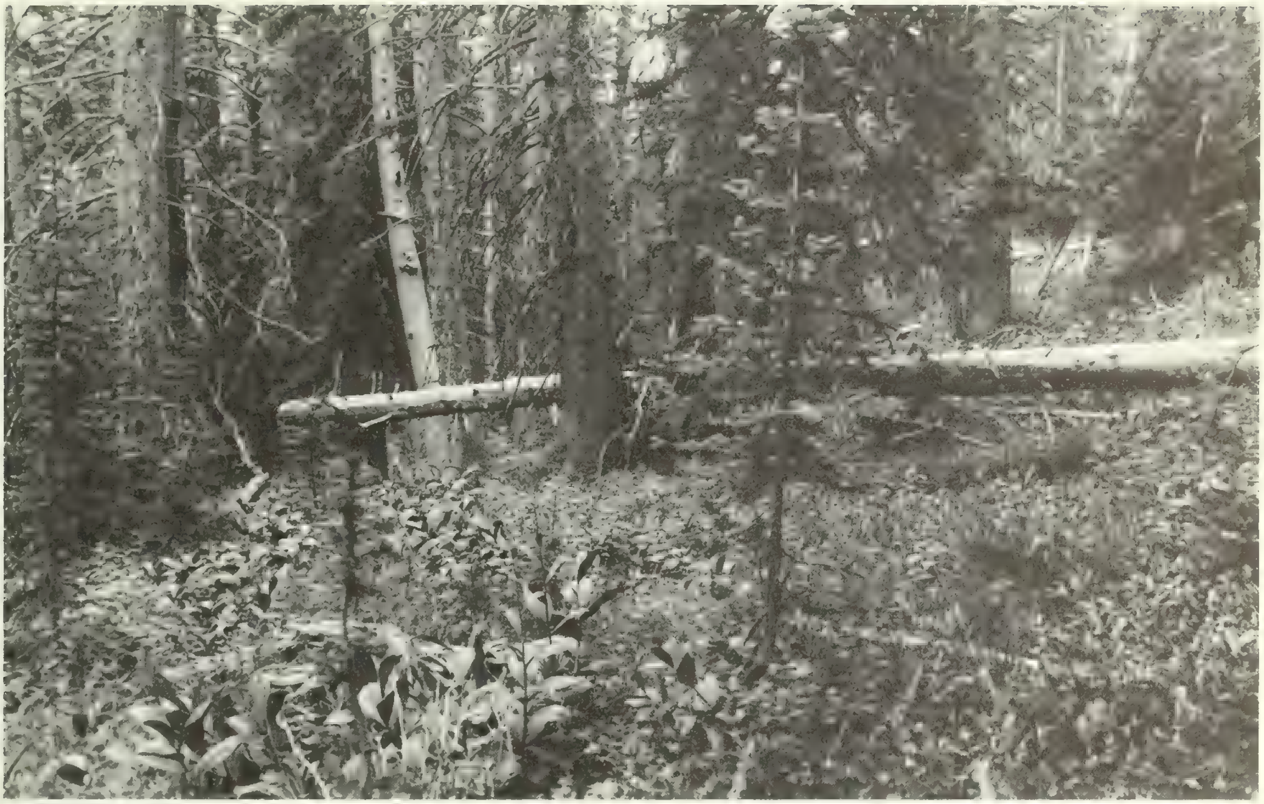


Figure 34.--Abies lasiocarpa/Calamagrostis canadensis *h.t.* (Calamagrostis *phase at 8,100 feet elev. on a seep-covered slope in the Beaverhead Range of southwestern Montana. The overstory is dominated by large* Picea *and smaller* Abies lasiocarpa. *The luxuriant undergrowth has* Veratrum viride, Senecio triangularis, Calamagrostis canadensis, *and* Ledum.

Wet-site graminoids and forbs and *Ledum glandulosum* characteristically dominate the undergrowth. *Calamagrostis canadensis* and *Senecio triangularis* are usually well-represented in the undergrowth. *Vaccinium scoparium* is abundant on drier hummocks, such as around the bases of large trees; *Vaccinium caespitosum* is prominent in one phase of the habitat type. Dwarf shrubs *Kalmia polifolia* and *Gaultheria humifusa* are sometimes present. *Dodecatheon jeffreyi, Ligusticum tenuifolium, L. canbyi, Streptopus amplexifolius, Veratrum viride,* and *Trollius laxus* are also characteristic of the *ABLA/CACA* h.t.

Calamagrostis canadensis (CACA) phase.--This is the commonest phase, representing the high-elevation conditions described above for the habitat type in general.

Galium triflorum (GATR) phase.--This phase occurs near the lower elevational limits of the habitat type, where it is transitional to warmer habitat types below, such as *ABLA/GATR* or *PICEA/EQAR*. Sample stands ranged from 5,800 feet in the Bitterroot Valley to 7,400 feet in south-central Montana. *Picea, Abies lasiocarpa,* and occasionally *Pinus contorta* constituted the tree flora of sample stands. *Calamagrostis canadensis* was accompanied in the undergrowth by *Galium triflorum* and *Ribes lacustre,* sometimes along with *Actaea rubra* and *Linnaea borealis,* indicating a milder climate.

Vaccinium caespitosum (VACA) phase.--This phase is also associated with the lower elevations of the habitat type, where it is often transitional to the *ABLA/VACA* h.t. on drier ground. A mosaic of *Carex* wet meadows, *ABLA/CACA* h.t., *VACA* phase, and

ABLA/CACA h.t. sometimes develops in flat basins where water-table depth is variable. This condition results from varying depth to an impermeable layer. Elevations of sample stands were about 5,000 feet in the Flathead Valley northwest of Kalispell and 7,000 to 7,400 feet in southwestern and central Montana. This phase contrasted with the others in having *Pinus contorta* as the dominant component of sample stands, while *Picea* and *Abies* are only minor components. Undergrowth is distinguished by *Vaccinium caespitosum* being associated with *Calamagrostis canadensis*. *Ledum* and *Linnaea borealis* were present in more than half of the sample stands.

Soil/Climate.--Soils in the *ABLA/CACA* h.t. were derived from a variety of noncalcareous parent materials (appendix D-1). Moist surface soils were acidic to very acidic sandy loams to silts. Most were nongravelly. Ground surfaces had little bare soil or rock exposed. Duff accumulations were extremely variable, ranging from almost none (in stream bottom sites subject to flooding) to depths of 10 to 15 cm in seepage or depression areas.

Climatic conditions for the *ABLA/CACA* h.t. are probably similar to those for *ABLA/VASC* (appendix D-2), except that the former probably has higher relative humidities and slightly cooler temperatures.

Fire history.--*ABLA/CACA* sites are apparently skipped by some of the lightning fires that burn the adjacent upland forest; but the abundance of *Pinus contorta* in sample stands suggests that occasional hot fires occur, probably during late-summer droughts.

Productivity/Management.--Timber productivity is moderate (appendix E). The *CACA* phase appears to have lower productivity than the other phases. *Picea* (attaining maximum heights of 90 to 120 feet in most stands) and *Pinus contorta* offer greatest potential for timber management. However, choice of cutting methods is largely restricted to clearcutting because of severe windthrow hazards associated with partial cutting on high-water-table sites. In narrow stringers along watercourses, light selection cutting (removing less than 30 percent of the basal area) can sometimes be done with little damage to the site or stand. Heavy equipment should not be used in the spring and early summer when water tables are highest.

Moderate summer use by deer and often by elk was evident in most sample stands in the *CACA* and *VACA* phases. Relatively heavy use by moose was noted in each of the *GATR* phase stands sampled. Domestic grazing values may be relatively high in early successional stages. However, cattle may churn the wet soils by trampling and severely limit conifer seedling establishment. Sites are poorly suited for roads, trails, or other developments. Protection of water resources is a major consideration in any management activity in this habitat type.

Other studies.--The 1974 review draft of our Montana classification treated the current *GATR* and *VACA* phases as *CACA* phases of the *ABLA/GATR* and *ABLA/VACA* h.t.s; the change places primary importance on *Calamagrostis canadensis* and its associates as indicators of seasonally water-saturated sites.

Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have used a more restrictive definition for *ABLA/CACA* in central Idaho, where it is accompanied by several other high-elevation wet types covering extensive areas. Cooper (1975) also described an *ABLA/CACA* h.t. in northwestern Wyoming.

Abies lasiocarpa/Linnaea borealis h.t.
(*ABLA/LIBO*; subalpine fir/twinflower)

Distribution.--*ABLA/LIBO* is associated with relatively moist, north-facing slopes and benches mostly at elevations of 5,000 to 7,000 feet, which are moderate for the *Abies lasiocarpa* series. It occurs rather commonly throughout the Montana Rockies.

Vegetation.--Seral stands are usually dominated by *Pseudotsuga, Pinus contorta,* and/or *Picea.* Undergrowth varies considerably by phase of the habitat type. Nevertheless, shrubs *Linnaea borealis, Lonicera utahensis, Vaccinium globulare,* and herbs *Calamagrostis rubescens, Arnica latifolia,* and *Pyrola secunda* occur throughout the type.

Linnaea borealis (LIBO) phase.--This phase was sampled in the vicinities of the Lolo, Bitterroot, Lewis and Clark, and Gallatin National Forests. It was largely restricted to north-facing slopes between 5,000 and 6,500 feet elevation, except on the Gallatin where it was found near 7,500 feet. *Pseudotsuga, Pinus contorta,* and *Picea,* (in order of decreasing abundance) were the major dominants in sample stands, along with *Abies lasiocarpa. Pinus ponderosa* and *Larix occidentalis* were major components of some seral stands in the Lolo and Bitterroot National Forests. Undergrowth is as described for the type with the frequent addition of *Amelanchier alnifolia* and *Rubus parviflorus.* Widely scattered individuals of either *Galium triflorum* or *Actaea rubra* are sometimes found, but this does not qualify the stand for inclusion in the more moist *ABLA/GATR* h.t.

Xerophyllum tenax (XETE) phase.--This phase was found only in the vicinities of the Flathead, Lolo, and Bitterroot National Forests, where it was occasional on all aspects between 4,500 and 6,000 feet. It gives way to the *ABLA/XETE* h.t., *VAGL* phase on drier sites, and to *ABLA/GATR* or *ABLA/CLUN* on more moist ones. Major associates of *Abies* in seral stands are (in order of decreasing abundance) *Pseudotsuga, Pinus contorta, Larix occidentalis,* and *Picea. Xerophyllum* and *Vaccinium globulare* form the dominant undergrowth in this phase, and are often accompanied by *Amelanchier alnifolia, Pachistima myrsinites, Rubus parviflorus,* and *Vaccinium scoparium* in addition to the characteristic typal species.

Vaccinium scoparium (VASC) phase.--This phase was found commonly on the Deerlodge and Beaverhead National Forests and in the Little Belt Mountains, where it was associated with gentle north slopes and benches between 6,300 and 7,300 feet. Like the *ABLA/VASC* and *ABLA/VAGL* h.t.s. that it adjoins on drier sites, it is usually dominated by seral stands of *Pinus contorta. Picea* and *Pseudotsuga* are minor components of most stands. A layer of *Vaccinium scoparium,* which has *Linnaea* and *Calamagrostis rubescens* growing with it, dominates the undergrowth. *Vaccinium globulare* may be present, but is seldom a major component of the undergrowth. Tom Lawrence, Kootenai National Forest, has also found this phase to be common between 4,600 and 5,300 feet on gentle slopes in the relatively dry mountains south and west of Eureka in northwestern Montana. Seral stands there are dominated mostly by *Larix occidentalis* and *Pinus contorta* with lesser amounts of *Picea* and *Pseudotsuga.*

Soil.--Our stands were on a variety of parent materials (appendix D-1). These were noncalcareous except for several stands in the *LIBO* phase. Surface soils in the *LIBO* phase were gravelly loams to silts with neutral to acidic reaction. Surface soils in the *VASC* phase were similar except for finer textures and greater acidity. Surface soils in the *XETE* phase were gravelly to very gravelly sandy loams to silts with acidic reactions. Ground surfaces generally had very little bare soil or rock exposed and moderate duff depths.

Productivity/Management.--Timber productivity ranges from low to high (appendix E). The *LIBO* and *XETE* phases appear to have the highest productivity; the *VASC* phase the lowest. Since *ABLA/LIBO* sites are generally located on well-drained uplands, they provide good opportunities for timber management. Our observations suggest that *Pseudotsuga* may often be frost-damaged when planted in the *VASC* phase. Value for domestic grazing is low. Light or sometimes moderate spring to fall use by deer and elk was evident in the sample stands; browse is limited, but stands provide good cover for big game. Water yield is moderately high.

Other studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) described a comparable *ABLA/LIBO* h.t. in central Idaho, and Cooper (1975) reported the type in the northwestern portion of Yellowstone National

Park, but nowhere else in northwestern Wyoming. In northern Idaho, R. and J. Daubenmire (1968) found *Linnaea* to be almost constantly associated with their "*Pachistima* union." In Montana various members of that union reach their eastern range limits: *Clintonia* drops out in northwestern Montana, and farther east the depauperate "*Pachistima* union" is represented by the *ABLA/GATR* h.t. (on very moist sites) and by the *ABLA/LIBO* h.t. (on moist, but better drained sites).

Abies lasiocarpa/Menziesia ferrugina h.t.
(*ABLA/MEFE*; subalpine fir/menziesia)

Distribution.--*ABLA/MEFE* is an abundant habitat type in the moist, higher elevation forests of western Montana (fig. 35). It extends eastward slightly beyond the Continental Divide, and includes an isolated population near Hebgen Lake in the Madison Range. *Menziesia's* distribution in the northern Rockies generally coincides with the area having a maritime climatic influence.

In northwestern Montana *ABLA/MEFE* generally occurs on all cool exposures between about 5,300 and 6,500 feet. It is restricted to the coolest, most sheltered slopes on the Bitterroot National Forest, but it is common there between 5,500 and 7,200 feet. In southwestern Montana, including the isolated occurrence near Hebgen Lake, it is restricted to cool, sheltered slopes between 6,700 and 7,500 feet. In northwestern Montana *ABLA/MEFE* is usually bordered below by *ABLA/CLUN* h.t., *MEFE* phase. Elsewhere it typically gives way below to *ABLA/LIBO* h.t. Usually at higher elevations it adjoins

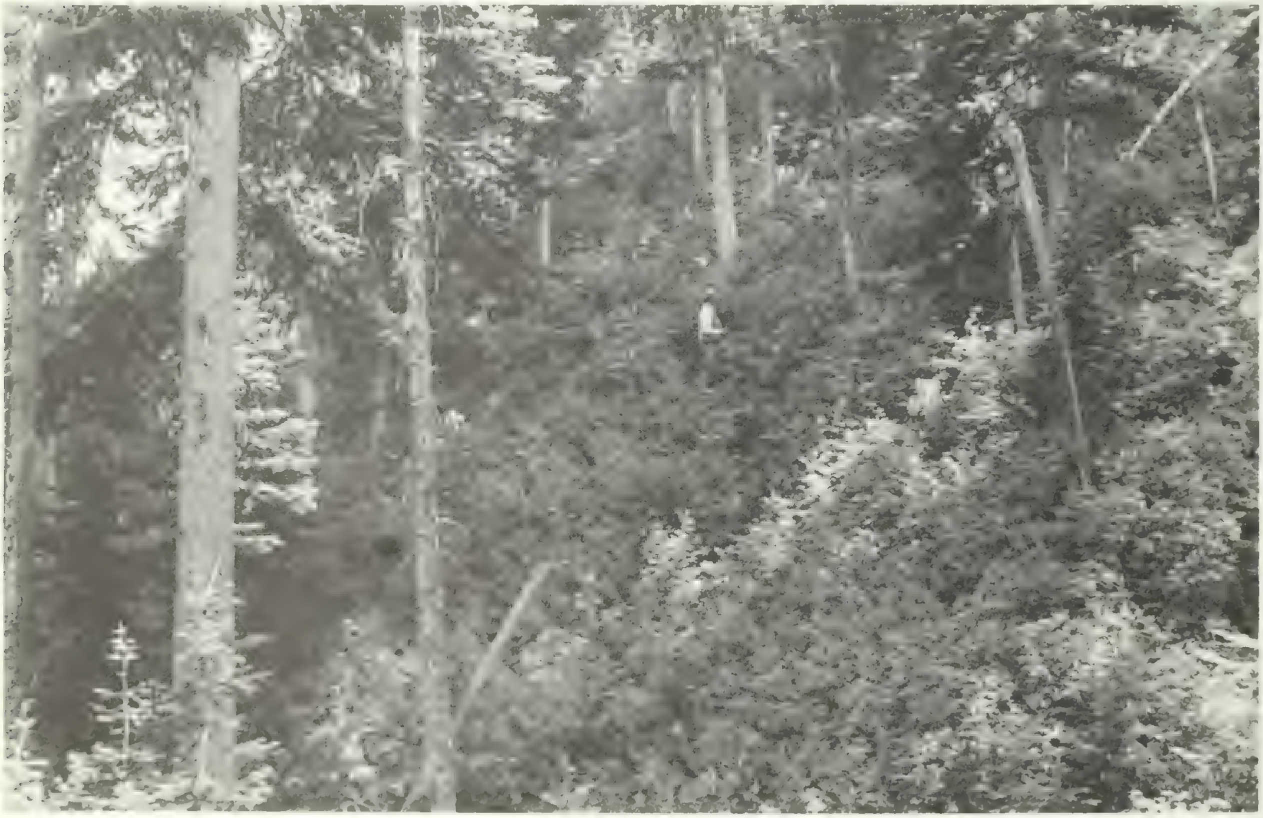


*Figure 35.--*Abies lasiocarpa/Menziesia ferruginea *h.t. on a steep north-facing slope (6,300 feet elev.) north of Hungry Horse Reservoir in northwestern Montana. The overstory is dominated by* Abies lasiocarpa *and* Picea; Menziesia *dominates the undergrowth.*

ABLA/LUHI h.t., *MEFE* phase. Approaching drier exposures it usually merges with *ABLA/XETE* h.t.; occasionally the transition forms a conspicuous zone having scattered *Menziesia* shrubs. At the edge of very wet sites *ABLA/MEFE* usually gives way to marsh or bog vegetation or to *ABLA/CACA* h.t.

Vegetation.--*Abies lasiocarpa* is usually the most abundant conifer in old-growth stands; however, large individuals of *Picea engelmannii* are often more conspicuous. *Pinus contorta* and frequently *Pseudotsuga* are the other common stand components. *Larix occidentalis* is often a seral component of stands in northwestern Montana.

Menziesia forms a patchy or dense layer usually 4 to 6 feet tall, often accompanied by *Alnus sinuata*. Beneath these shrubs, *Vaccinium globulare, V. scoparium, Xerophyllum tenax*, and *Arnica latifolia* are usually well represented. *Pyrola secunda, Viola orbiculata*, and a few other scattered forest herbs are also characteristically present.

In southwestern Montana, *Menziesia* is often only 3 to 4 feet tall, with obvious frost damage to the tallest shoots, presumably because of inadequate snowpack protection during subzero winter temperatures.

Soil/Climate.--Soils in the *ABLA/MEFE* h.t. were derived from a variety of noncalcareous parent materials (appendix D-1). Surface soils were gravelly (28 percent) loams to silts with very acidic to acidic reactions (mean pH 4.9). Ground surfaces had almost no bare soil or rock exposed; duff depth averaged 4.7 cm.

Weather data from Burke, Idaho (appendix D-2) should approximate climatic conditions in *ABLA/MEFE* h.t.s in northwestern Montana.

Productivity/Management.--Timber productivity is moderate to high (appendix E). with several commercial species well adapted to these sites (appendix B). However, intensive management for timber production presents some major problems. Partial cutting leads to an increase in the shade-tolerant *Abies lasiocarpa* or to a lack of regeneration under the dense *Menziesia ferruginea* and *Alnus sinuata* undergrowth. Clearcutting is recommmended to establish vigorous second-growth stands of seral species. Site preparation is essential and can be accomplished by dozer scarification on gentler slopes. However, on steep slopes prescribed burning is the only feasible method. Unfortunately, fuels on these slopes remain moist, leaving only a brief period in certain years when successful burning can be accomplished. The silvicultural recommendations of Roe and DeJarnette (1965) and Boyd and Deitschman (1969) are probably applicable to this habitat type as well as *TSME/MEFE*.

Watershed value is high; maintaining or improving water yields by regulating flows should be considered in any management actions. Elk often make extensive use of this habitat type for both cover and forage during the summer and fall. There is no potential for domestic grazing. Recreational use is severely limited by dense undergrowth and steep slopes.

Other studies.--R. and J. Daubenmire (1968) described an *Abies lasiocarpa/Menziesia ferruginea* h.t. in northern Idaho and eastern Washington that predominates on cool aspects at higher elevations. Three of their stands (numbers 134, 137, and 159) appear comparable to our *ABLA/MEFE* h.t. The remainder of their stands are evidently similar to our *ABLA/LUHI* h.t., *MEFE* phase. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have found *ABLA/MEFE* h.t. extending southward into west-central Idaho. Ogilvie (1962) described a similar habitat type occurring between about 5,000 and 5,800 feet in southwestern Alberta; he found the soils to be highly podzolized, strongly leached, and very acidic. Franklin and Dyrness (1973) discuss an *Abies amabilis/Menziesia* association found on high, cool exposures in the Cascade Mountains of Oregon and Washington.

Tsuga mertensiana/Menziesia ferruginea h.t.
(*TSME/MEFE*; mountain hemlock/menziesia)

Distribution.--This habitat type is distinguished from *ABLA/MEFE* by the presence of successfully reproducing *Tsuga mertensiana*. *TSME/MEFE* is associated with mountain climates having an especially strong oceanic influence; it is restricted to the border region of northwestern Montana between Lolo Pass and Libby, where it is found at between 5,400 and 6,400 feet. Many of our *Tsuga mertensiana* sample stands came from Habeck (1967). Along the Montana-Idaho Divide west of St. Regis, this habitat type gives way to *TSME/LUHI* h.t., *MEFE* phase above about 6,000 feet, whereas on the next mountain range east (presumably not having such an extremely heavy snowfall) it extends higher. It is bordered on dry exposures by the *TSME/XETE* or *ABLA/XETE* h.t.s, and at lower elevations by the *ABLA/CLUN* h.t., *MEFE* phase.

Vegetation.--*Tsuga* may be either the climax dominant or a coclimax with *Abies lasiocarpa*. Sample stands were dominated by *Tsuga* and *Abies* with only small amounts of *Picea engelmannii, Larix occidentalis, Pinus monticola,* and *Pseudotsuga menziesii* (in order of decreasing abundance). Undergrowth is similar to that of the *ABLA/MEFE* h.t.

Soil.--Soils appear similar to those of the *ABLA/MEFE* h.t. (appendix D-1).

Productivity/Management.--This is similar to that for *ABLA/MEFE* except that seral conifers are often only minor components of natural stands.

Other studies.--This habitat type has been described in northern Idaho by R. and J. Daubenmire (1968), where it is apparently more extensive. Three of their sample stands (numbers 12, 63, and 132) appear comparable to our *TSME/MEFE* h.t. in Montana. The remainder of their stands are evidently similar to our *TSME/LUHI* h.t., *MEFE* phase.

Abies lasiocarpa/Xerophyllum tenax h.t.
(*ABLA/XETE*; subalpine fir/beargrass)

Distribution.--*ABLA/XETE* makes up a major portion of the *Abies lasiocarpa* series west of the Continental Divide in Montana, where it is usually associated with steep, dry exposures between 5,200 and 7,000 feet elevation. The eastern limits of *Xerophyllum tenax* are generally correlated with fringes of the maritime climatic influence. An isolated occurrence of *Xerophyllum* (and *ABLA/XETE* h.t.) far beyond its normal limits was noted in the vicinity of Elephanthead Peak, southeast of Livingston.

Vegetation.--*Abies lasiocarpa* is the indicated climax species and *Picea* is a minor component of most stands. *Pinus contorta* is a seral dominant throughout the type, but *Pseudotsuga's* role varies by phase. *Pinus albicaulis* is a minor component in many stands.

In addition to *Xerophyllum tenax*, undergrowth species occurring through the habitat type include *Vaccinium scoparium, Calamagrostis rubescens, Carex geyeri, Arnica latifolia,* and *Pyrola secunda*.

Vaccinum globulare (VAGL) phase.--This phase is abundant on relatively dry slopes and ridges between 5,000 and 6,300 feet in northwestern and west-central Montana. Elevations are somewhat higher near the southern and eastern limits (fig. 36). It typically merges with *ABLA/MEFE* on moist exposures; with *ABLA/LUHI* h.t., *VASC* phase at higher elevations; and with *PSME/VAGL* h.t., *XETE* phase on drier and warmer sites.

Pseudotsuga and *Pinus contorta* typically dominate seral stands, with *Larix occidentalis* and *Pinus monticola* present in lesser amounts. *Picea engelmannii* is

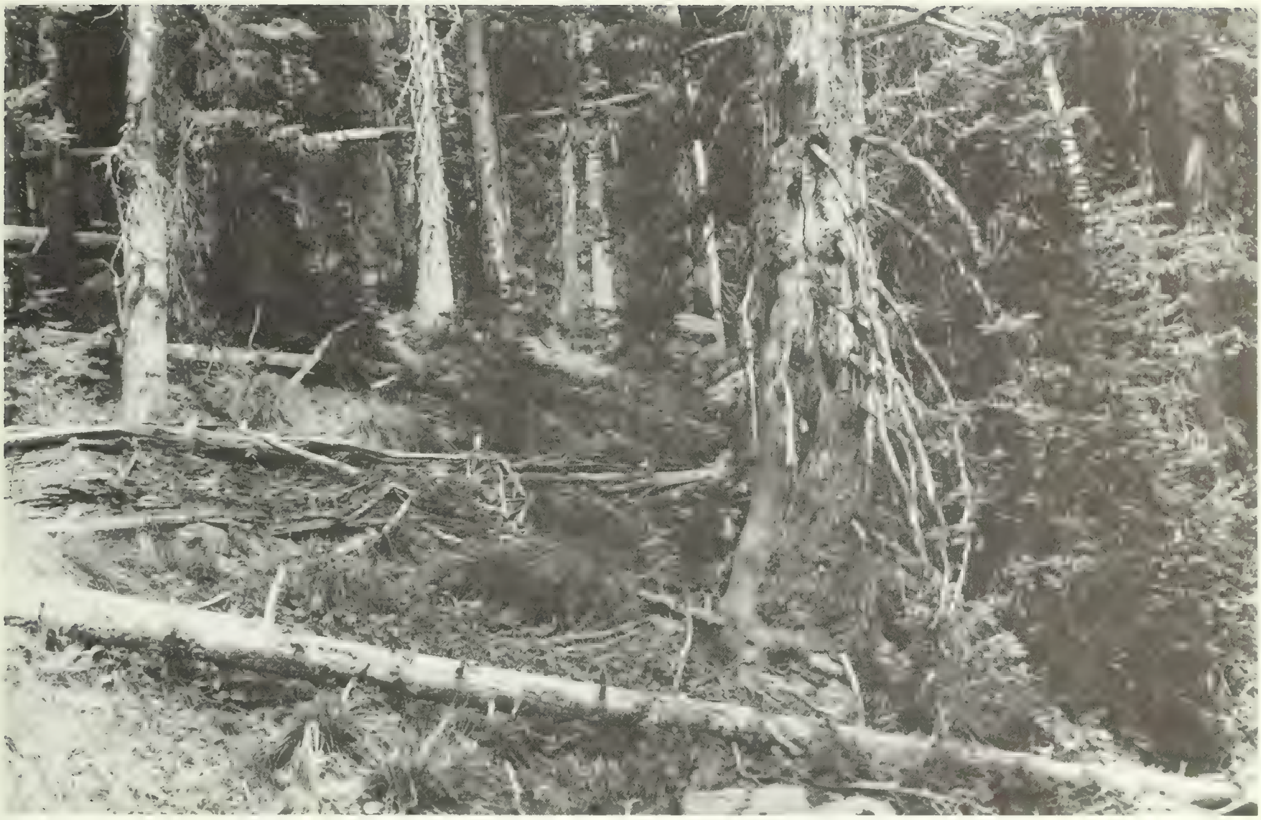


Figure 36.--Vaccinium globulare *phase* (ABLA/XETE *h.t.) on a south-facing slope (at an unusually high elevation of 8,100 feet) in the Beaverhead Range of southwestern Montana. Older* Picea *and all-aged* Abies lasiocarpa *make up the overstory of this 250-year-old stand.* Xerophyllum *and* Vaccinium globulare *are the principal undergrowth species.*

common as a minor component in all but the driest, south-facing slopes, where *Viola orbiculata* is also conspicuously absent.

Undergrowth is dominated by *Xerophyllum* and *Vaccinium globulare*, with minor coverages of *Pachistima myrsinites*, *Thalictrum occidentale*, and other species listed previously for the type. This phase is similar to the *ABLA/XETE* h.t., *VAGL* phase defined for central Idaho by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station). It is also similar to R. and J. Daubenmire's (1968) *Abies lasiocarpa/Xerophyllum tenax* h.t. in northern Idaho, (except for stands 57 and 127, which are comparable to our *ABLA/LUHI* h.t., *VASC* phase).

Vaccinium scoparium (VASC) phase.--This phase represents the habitat type near its eastern limits, in the broad zone where it is transitional to the *ABLA/VASC* h.t. It was found extensively between 6,000 and 7,500 feet in west-central Montana near the Continental Divide. This phase is typically found on gentle slopes, cool, well-drained benches, or on cooler aspects than the *VAGL* phase. *Pinus contorta* is the dominant seral species (fig. 37). *Pseudotsuga* is widely scattered and apparently is frost-stunted. This phase is generally beyond the range limits of *Larix occidentalis*. Other conifers occur as described previously for the type. Undergrowth contrasts with that of the *VAGL* phase in that *Vaccinium globulare* is scattered or absent, *Xerophyllum* coverage is reduced, and *Vaccinium scoparium* is dominant. Nearly all sample stands were dominated by seral *Pinus contorta*, suggesting that extensive lightning fires occur periodically.

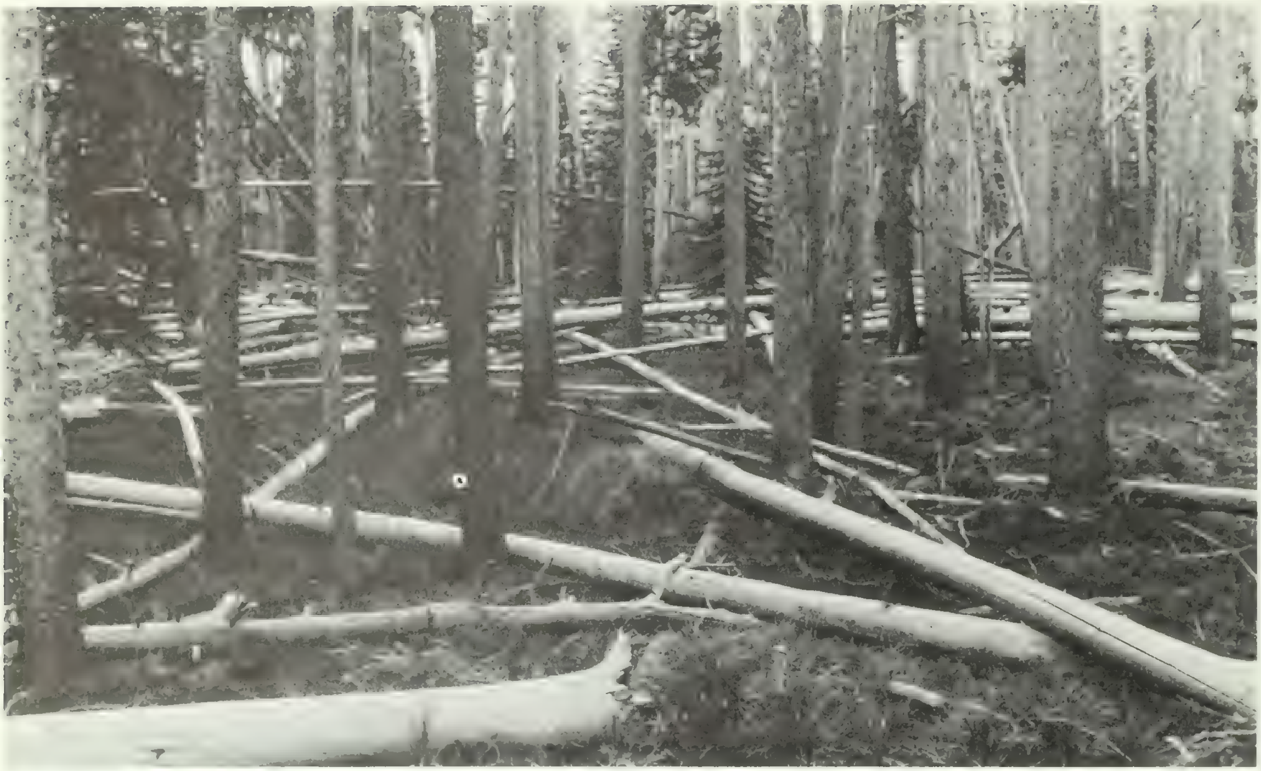


Figure 37.--Vaccinium scoparium *phase (*ABLA/XETE *h.t.) atop a level ridge (7,500 feet elev.) northeast of Wisdom in southwestern Montana. Seral* Pinus contorta *dominates the overstory along with scattered* Picea; Abies lasiocarpa *forms the bulk of the regeneration.* Vaccinium scoparium *dominates in the undergrowth;* Xerophyllum *is scattered about.*

Weather data for Summit (Marias Pass) in appendix D-2 shows this to be a cold, snowy, forest environment, with a winter climate more severe than that of the *VAGL* phase.

This phase has much in common with the *ABLA/VASC* h.t., which becomes extensive eastward in more continental and generally drier climates. Several of Robert Steele and others' (1975 preliminary draft, USDA Forest Service, Intermountain Station) sample stands (in their *ABLA/XETE* h.t., *XETE* phase) in central Idaho would evidently fit our *VASC* phase.

Soil.--Soils in the *ABLA/XETE* h.t. were derived from a variety of noncalcareous parent materials (appendix D-1). Surface soils were gravelly sandy loams to silts. Reactions were primarily acidic in the *VAGL* phase (mean pH 5.1) and very acidic in the *VASC* phase (mean pH 4.6). Ground surfaces had little bare soil and rock exposed; duff depth averaged about 3.5 cm.

Productivity/Management.--Timber productivity ranges from low to high (appendix E); highest values are generally in the *VAGL* phase. The *VAGL* phase offers opportunities for mixed species management, but prompt establishment of regeneration may require both site preparation and shade. *Pseudotsuga* and *Pinus contorta* appear to offer the greatest potential for timber management. In the *VASC* phase, timber management is generally limited to *Pinus contorta*. However, regeneration may be easier to obtain on these cooler aspects, and the gentler terrain is better suited for intensive timber management.

Browse production for deer and elk is moderate in the *VAGL* phase and low in the *VASC* phase. Evidence of light to moderate summer and fall use by deer and elk is present in most stands. Occasional use by moose is evident in the *VASC* phase.

Domestic grazing potential is generally low. Watershed management should recognize the moderately high precipitation coupled with high evapotranspiration and runoff rates on southerly exposures. Snowpack in this habitat type (especially in the *VAGL* phase) may melt periodically during winter and disappear in the spring several weeks earlier than in adjacent types.

Tsuga mertensiana/Xerophyllum tenax h.t.
(*TSME/XETE*; mountain hemlock/beargrass)

Distribution.--*TSME/XETE* occurs only sparingly in Montana. It is found mostly at 5,500 to 6,500 feet elevation on upper slopes and ridges in the extreme northwestern part of the State, between Lolo Pass and Libby. In northern Idaho it commonly occupies the warm exposures, but eastward from the Idaho-Montana Divide comparable exposures often lack *Tsuga* and are characterized by the *ABLA/XETE* h.t., *VAGL* phase.

Vegetation.--Vegetation of the *TSME/XETE* h.t. appears generally similar to that described for the *ABLA/XETE* h.t., *VAGL* phase, except that *TSME/XETE* is associated with a moist, more strongly maritime climate. Seral stands in the *TSME/XETE* h.t. are less likely to have *Pseudotsuga* than those of the *ABLA/XETE* h.t., *VAGL* phase, but they are more likely to have *Pinus monticola.*

Soil.--Soils were similar to those described for the *ABLA/XETE* h.t., *VAGL* phase (appendix D-1).

Productivity/Management.--This is similar to that described for the *ABLA/XETE* h.t., *VAGL* phase.

Other studies.--Three of R. and J. Daubenmire's (1968) *Tsuga mertensiana/Xerophyllum* h.t. stands in northern Idaho (numbers 47, 98, and 157) are comparable; the remainder of their stands are similar to our *TSME/LUHI* h.t., *VASC* phase.

Abies lasiocarpa/Vaccinium globulare h.t.
(*ABLA/VAGL*; subalpine fir/blue huckleberry)

Distribution.--*ABLA/VAGL* is a moderately moist upland type occurring mostly on north- or east-facing slopes or occasionally on cool benches, usually between 6,800 and 7,800 feet elevation. It is largely restricted to areas near or east of the Continental Divide, and is common in the vicinity of the Gallatin National Forest. *ABLA/VAGL* often alternates in a mosaic with the *ABLA/VASC* h.t. (especially the latter's *CARU* phase), the former apparently occupying more moist or more sheltered microsites.

Vegetation.--*Abies lasiocarpa* is the apparent climax, with seral stands usually dominated by *Pinus contorta* or *Pseudotsuga. Picea engelmannii* (or *P. engelmannii* X *glauca)* is a common though minor component of most stands, and *Pinus albicaulis* is a rather prominent minor species in some stands. These latter stands were not classified *ABLA-PIAL/VASC* h.t. because *Pseudotsuga* was present.

Undergrowth is luxuriant for east-side *Abies lasiocarpa* types. *Vaccinium globulare* forms a patchy layer a foot high. *Vaccinium scoparium* is also usually well represented, but other shrubs occur only in minor amounts. *Carex geyeri, Calamagrostis rubescens,* and *Arnica cordifolia* are common in more than half of the stands; small coverages of *Osmorhiza chilensis, Pyrola secunda,* and *Thalictrum occidentale* are also characteristic.

Soil.--Soils in the *ABLA/VAGL* h.t. were derived from a wide variety of parent materials (appendix D-1). Surface soils were acidic gravelly loams to silty clay loams. Ground surfaces had little bare mineral soil or rock exposed; duff was moderately deep (average 5.3 cm).

Productivity/Management.--Timber productivity is low to moderate (appendix E-4). *Pinus contorta* should be easier to regenerate than other species. Sample stands showed light to moderate use by deer and elk with occasional use by moose and bears. Domestic grazing use is quite limited, but watershed values are relatively high. Most of the denser stands of *Vaccinium globulare* east of the Continental Divide are limited to this habitat type, so management to enhance berry production may be an important consideration. However, silvicultural prescriptions to increase amounts of *Vaccinium globulare* and berry production are not known at this time, and it would be unwise to extrapolate from other habitat types or from areas where different species of *Vaccinium* have been studied. Responses of *Vaccinium globulare* to various types of vegetative manipulation need to be studied.

Other studies.--In central Idaho, Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have described a generally similar *ABLA/VAGL* h.t. that also occurs largely beyond the range limits of *Xerophyllum*. Cooper (1975) described this habitat type as reaching its maximum development in northeastern Idaho and northwestern Wyoming.

Abies lasiocarpa/Vaccinium scoparium h.t.
(*ABLA/VASC*; subalpine fir/grouse whortleberry)

Distribution.--This is one of the most abundant forest habitat types near and east of the Continental Divide in Montana. It occurs mostly on well-drained soils on broad ridges, gentle slopes, and benches between about 7,000 and 8,500 feet. It is typically bounded at higher elevations by the *ABLA-PIAL/VASC* h.t., on drier sites by *ABLA/CARU* or *PSME/CARU* h.t.s, and on more moist sites by several of the moist *Abies lasiocarpa* h.t.s. (*ABLA/VASC* is also locally common at 5,000 to 5,700 feet in the relatively dry mountains south and west of Eureka in northwestern Montana.)

Vegetation.--*Abies lasiocarpa* is the indicated climax and *Pinus contorta* is the dominant seral species throughout the habitat type. *Picea engelmannii* is a major component in only the *THOC* phase. *Pseudotsuga* is a major seral component in the *CARU* phase, but becomes scarce and often frost stunted as it reaches its upper limits in the other two phases. (*Larix occidentalis* shares dominance with *Pinus contorta* in seral stands near Eureka, based on recent inventory data provided by Tom Lawrence, Kootenai National Forest.)

Undergrowth is dominated by a low-shrub layer of the *Vaccinium scoparium*, or occasionally by *V. myrtillus*. Where *V. myrtillus* is associated with more moist or milder environmental conditions that *V. scoparium*, indicators of other habitat types are usually present. Thus, *V. myrtillus* can be used as an alternate indicator of the *ABLA/VASC* h.t. without implying ecological equivalence of the two species. We also favored this approach because of the difficulty in taxonomically separating the two species. Other species in the undergrowth are inconspicuous, except for modest coverages of *Arnica latifolia* or *A. cordifolia*, *Carex geyeri*, and *Calamagrostis rubescens*

Calamagrostis rubescens (CARU) phase.--This occurs in a warmer environment than other phases of the habitat type. It is found mostly between elevations of 5,200 and 7,100 feet, averaging almost 1,000 feet lower than the other phases. Although it is widespread east of the Continental Divide, it is less extensive than the *VASC* phase. This phase is usually bounded on cooler sites by other phases of the *ABLA/VASC* h.t., on drier sites by the *PSME/CARU* h.t., and on more moist sites by the *ABLA/VAGL* h.t. Although *Abies lasiocarpa* is the indicated climax, sites are often near the species' lower altitudinal (drought) limits and this tree is not particularly vigorous. Most sample stands are dominated by seral *Pinus contorta* and *Pseudotsuga*. *Picea* is only a minor component of stands in this phase. The undergrowth is dominated by *Vaccinium scoparium*, but several species characteristic of milder environments are conspicuous in this phase. *Calamagrostis rubescens* is common and either *Arctostaphylos uva-ursi* or *Berberis repens* are present. Additional species present may include *Juniperus communis*, *Spiraea betulifolia*, and *Vaccinium globulare*.

Vaccinium scoparium (VASC) phase.--Stands not meeting the criteria for the *CARU* or *THOC* phases are classified here. This is the most abundant phase of the habitat type in Montana. It occupies cold, relatively dry sites, usually on flat areas or gentle slopes between 7,000 and 8,000 feet elevation. It is common in southwestern and south-central Montana as well as in the Little Belt Mountains, and occasionally is found west of the Continental Divide.

Pinus contorta is the major dominant conifer on most sites and succession to climax dominance by *Abies lasiocarpa* is often very slow either because of lack of seed source or apparent low vigor in this phase. *Pseudotsuga*, if present, is often frost-stunted. *Picea* is usually scarce. Undergrowth is as described previously for the type.

The abundance of this phase in central and southwestern Montana and central Idaho (Robert Steele and others 1975 preliminary draft, USDA Forest Service, Intermountain Station) seems to be related to the scant summer precipitation in combination with well-drained upland soils.

Thalictrum occidentale (THOC) phase.--This phase occupies the moist, cool environments within the habitat type. Sample stands ranged from 7,300 to 8,600 feet in elevation and were common only in the Beaverhead and Gallatin National Forests. This is the only phase having *Picea* as a major component, sharing dominance about equally with *Abies lasiocarpa* and *Pinus contorta*. Stands in this phase have *Thalictrum occidentale* common or *Valeriana sitchensis* or *Viola orbiculata* present; also they do not meet the criteria for the *CARU* phase. In addition, *Osmorhiza chilensis* and *Pyrola secunda*, not found in the drier *VASC* phase, are usually present here.

Soil/Climate.--Soils in the *ABLA/VASC* h.t. were derived from a wide variety of parent materials with some differences by phase as shown in appendix D-1. Surface soils in the *VASC* phase were gravelly sandy loams to silts; those in the *CARU* and *THOC* phases had less gravel and were finer in texture. Soils in all phases were acidic to very acidic. Ground surfaces had small amounts of rock and very little bare mineral soil exposed. Duff was moderate in the *VASC* phase (average 3.5 cm) to moderately deep in the *THOC* phase (average 5.6 cm).

Weather data from Kings Hill (appendix D-2) reflect the climate of a relatively moist and cold site in this habitat type.

Fire history.--The preponderance of mature, even-aged stands of *Pinus contorta* in this habitat type is generally attributable to intense wildfires, which often follow severe outbreaks of mountain pine beetle (*Dendroctonus ponderosae* Hopk.). This fire history may also have contributed to lack of seed source of climax species. However, fire scars on old-growth (150 to 250 years) *Pinus contorta* trees in several sample stands indicate that one to three noncatastrophic ground fires occurred after initial stand establishment. No doubt this strongly influenced current stand structure.

Productivity/Management.--Timber productivity is low to moderate (appendix E), with highest productivities in the *CARU* and *THOC* phases. Extensive areas of gentle terrain are suitable for timber management. Existing stands of *Pinus contorta* could be managed for small sawtimber, pulpwood, posts, and poles. This species should do best under even-aged management systems. *Pseudotsuga* is generally available for timber production in the *CARU* phase; but regeneration may require scarification because of grass sod. In the *THOC* phase, *Picea* is also available; stands with overstories of

Pinus contorta and vigorous understories dominated by *Picea* offer opportunities for partial cutting. According to Roe and Amman (1970), the risk of *Pinus contorta* loss to mountain pine beetle epidemics is less in this habitat type than in lower elevation habitat types, and smaller trees are less susceptible than large ones.

Forage potential for big game or domestic stock is extremely low in forest stands. Clearcuts may produce 800 to 1,000 pounds of forage per acre per year, but palatability ratings are only fair for the native early-successional plants (Basile and Jensen 1971).

Water yield is relatively high, and management constraints may be needed to protect water resources.

Other studies.--*Abies lasiocarpa* and *Picea engelmannii/Vaccinium scoparium* habitat types have been described elsewhere in the Rockies by R. and J. Daubenmire (1968), McLean (1970), Pfister (1972a), Reed (1969, 1976); Wirsing (1973), Hoffman and Alexander (1976), and Cooper (1975). The abundance of *Picea* and the presence of moist indicator forbs suggest that most of their stands are similar to our *THOC* phase. However, the *CARU* phase has also been described in south-central British Columbia (McLean 1970), central Idaho (Robert Steele and others 1975 preliminary draft, USDA Forest Service, Intermountain Station), and northwestern Wyoming (Cooper 1975). In addition, Robert Steele and others (1975) reported the *VASC* phase from central Idaho.

Abies lasiocarpa/Alnus sinuata h.t.
(*ABLA/ALSI*; subalpine fir/Sitka alder)

Distribution.--*ABLA/ALSI* is a relatively cool and moist upland habitat type within the lower subalpine forest. Most stands are located on north-facing slopes between 6,500 and 7,500 feet elevation, except in northwestern Montana, where they occur at 5,000 to 5,800 feet. The type is rather widely distributed in the higher mountains of the State; however, stands are usually scattered and not extensive.

In west-central Montana *ABLA/ALSI* sometimes forms a transitional zone between the *ABLA/MEFE* h.t. and the *ABLA/XETE* h.t., *VASC* phase. Eastward *ABLA/ALSI* might be considered to be an extension of sites similar to *ABLA/MEFE*. but beyond the geographic limits of *Menziesia*.

ABLA/ALSI is often bordered below--on warmer, but similarly moist sites--by *ABLA/LIBO* stands in which *Alnus sinuata* is well represented. East of the Continental Divide the adjacent drier habitat types are *ABLA/VASC* or *ABLA/VAGL*.

Stands are dominated to varying degrees by *Pinus contorta*, *Picea engelmannii*, *Abies lasiocarpa*, and occasionally by *Pseudotsuga*. *Larix occidentalis* is often a major component west of the Continental Divide. Undergrowth is a relatively dense or a patchy layer of *Alnus*, sometimes with *Vaccinium globulare*, *V. scoparium*, or *Xerophyllum* also well represented. Scattered *Pyrola secunda*, *Arnica latifolia*, and similar forbs are also typical.

Since all stands observed were 200 years old or less, retention of *Alnus* at the theoretical climax is uncertain. Nevertheless, the vegetation and environment are distinctive enough to warrant designation as a habitat type.

Soil.--Our stands were on a variety of noncalcareous parent materials (appendix D-1). Surface soils were loams to silts with very acidic to acidic reactions. Gravel content averaged 18 percent. Ground surfaces generally had no bare soil or rock exposed; duff depth averaged 6.0 cm.

Productivity/Management.--Timber productivity is moderate (appendix E); *Pinus contorta* and *Picea* are prominent seral components. Big-game use appears to be light, although stands may be important for cover. Water yield should be relatively high. The presence of *Alnus sinuata* suggests that water tables may be high during part of the year; this would create problems for certain management activities. Conifers should reestablish readily following major overstory removal or wildfire; however, tree growth may sometimes be retarded initially by the development of an *Alnus*-dominated brushfield.

Other studies.--Although *Alnus sinuata* also forms a dominant undergrowth in seep areas and under seral conditions in many moist habitat types (R. and J. Daubenmire 1968), these situations are *not* included in our definition of the *ABLA/ALSI* h.t. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) mentioned finding a similar *ABLA/ALSI* habitat type in east-central Idaho.

Abies lasiocarpa/Calamagrostis rubescens h.t.
(*ABLA/CARU*; subalpine fir/pinegrass)

Distribution.--*ABLA/CARU* was found only east of the Continental Divide in Montana, where it occurs on moderate slopes and all aspects near the warm, dry limits of the *Abies lasiocarpa* series. It is most extensive on the Gallatin National Forest and in the Centennial Mountains between 6,500 and 7,700 feet. It is also common in the Front Range west of Great Falls on limestone substrates between 5,800 and 6,300 feet.

Vegetation.--*ABLA/CARU* is apparently an extension of the *PSME/CARU* h.t. on slopes moist and cool enough for *Abies lasiocarpa*. *Pseudotsuga* and *Pinus contorta* dominate most stands, with *Abies* and *Picea* being minor stand components. Wildfire evidently sweeps through most stands often enough to set back invasion of *Abies* and *Picea* without destroying large *Pseudotsugas*, which may attain diameters of 3 feet and heights of 90 feet.

Undergrowth is dominated by *Calamagrostis rubescens* and resembles that of the *PSME/CARU* h.t, except in having greater coverages of forbs like *Thalictrum occidentale*, *Osmorhiza chilensis*, and *Pyrola secunda*. The mat of *Calamagrostis rubescens* and *Carex geyeri* is especially luxuriant in young or open stands. However, near the upper limits of the *ABLA/CARU* h.t. these rhizomatous graminoids have less vigor and give way to undergrowth dominated by forbs of the *ABLA/ARCO* h.t. or to *Vaccinium scoparium* or *V. globulare*. In some areas (e.g., the Centennial Mountains) there seems to be a broad transition between *ABLA/CARU* at its upper limits, and *ABLA/ARCO*.

Soil.--Our stands were primarily on sedimentary parent materials (appendix D-1). Surface soils were acidic sandy loams to silts with average gravel content of 21 percent. Ground surfaces had little or no bare soil or rock exposed. Duff averaged 4.3 cm deep.

Productivity/Management.--Timber productivity ranges from low to high (appendix E-4). *Pseudotsuga* and *Pinus contorta* are major components of seral stands. Some mechanical scarification may be necessary to obtain conifer regeneration following harvest cuttings. However, many stands have advance regeneration of *Picea*, *Abies*, and even *Pseudotsuga* that could be managed following careful removal of the overstory. Light to moderate deer and elk use is evident in most stands. Cattle also make light use of stands on gentle topography. The potential for domestic forage production may be fairly good in early successional stages of this type--better than in other habitat types in the *Abies lasiocarpa* series. However, we do not know of any studies on forage production or grazing potential in this habitat type.

Other studies.--A similar *ABLA/CARU* h.t. has been described by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) as being abundant in central Idaho. However, in western Wyoming, Cooper (1975) sampled only two stands (numbers 227 and 229) that seem comparable to this habitat type. Ogilvie (1962) described a *Picea-Abies/Calamagrostis* h.t. in Alberta, but the limited stand data show it to be comparable to our *ABLA/VACA* h.t.

Abies lasiocarpa/Clematis pseudoalpina h.t.
(*ABLA/CLPS;* subalpine fir/virgin's bower)

Distribution.--*ABLA/CLPS* represents the lower (warm, dry) limits of the *Abies lasiocarpa* series on calcareous substrates east of the Continental Divide in Montana (fig 38). It is an edaphically controlled forest environment in that all 15 sample stands (and all other stands observed) were on limestone or on other substrates containing layers of lime-rich material. The type is locally abundant in many of the high mountains east of the Divide where lime-rich rocks are prevalent (e.g., Little Belt Mountains at 7,000 to 7,500 feet, Big Snowies at 6,000 to 6,800 feet, and Pryor Mountains near 8,000 feet). It was found on all exposures, but was most common on steep south- or west-facing slopes.

Adjacent cooler or more moist sites on calcareous substrates often support the ABLA/ARCO h.t.; warmer sites often support habitat types in the *Pseudotsuga* or *Pinus flexilis* series,or grassland. On adjacent sites having noncalcareous rock substrates, the habitat type is likely to be *ABLA/VASC*, *ABLA/VAGL,* or *ABLA/CARU,* with seral stands dominated by *Pinus contorta.*

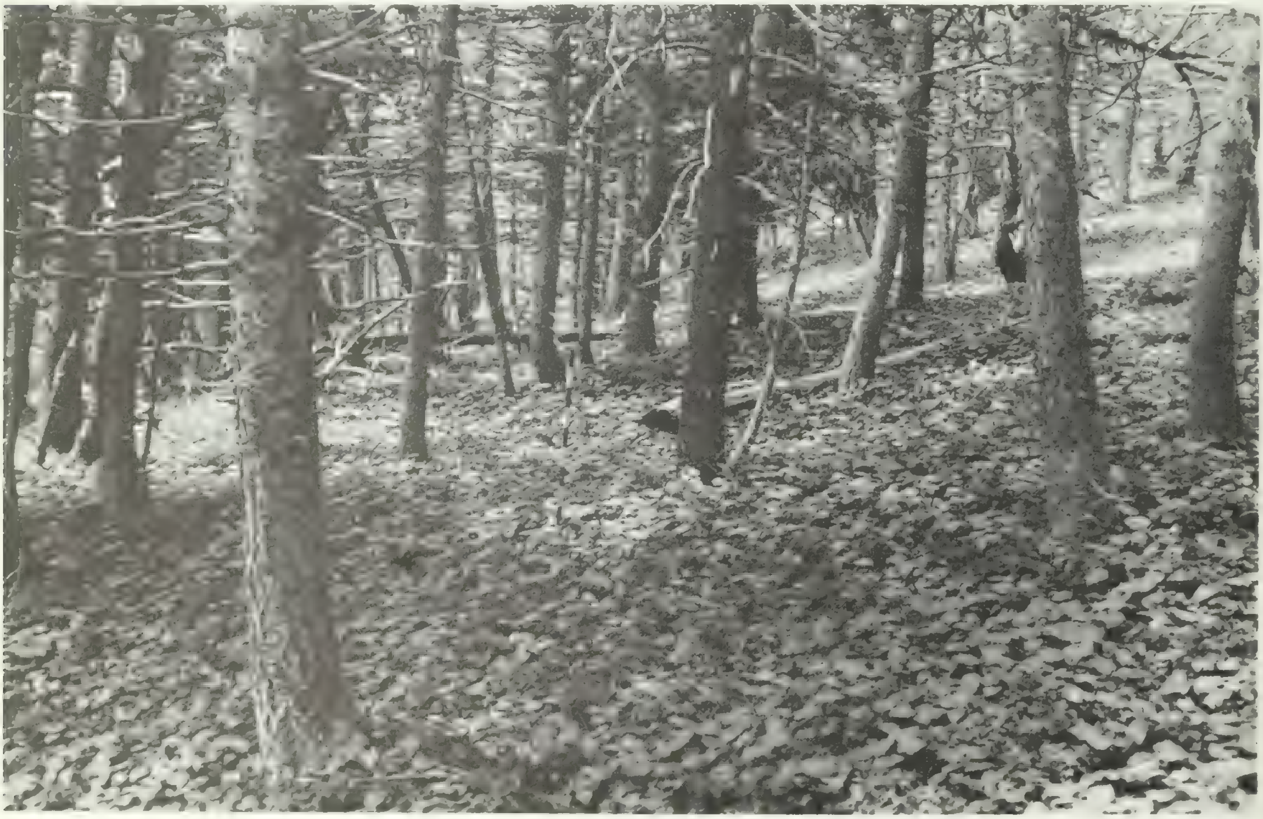


Figure 38.--Abies lasiocarpa/Clematis pseudoalpina *h.t. on a gentle south-facing slope (7,500 feet elev.) on limestone substrate near Red Lodge in south-central Montana. Seral* Pseudotsuga *and* Pinus flexilis *dominate the overstory while* Abies lasiocarpa *and* Picea *are dominant in the regeneration layer.* Arnica cordifolia *and* Clematis pseudoalpina *are the dominant undergrowth species in view here.*

Vegetation.--Although *Abies lasiocarpa* is present at more than 10 trees per acre, and for purposes of this classification is the "indicated climax," it often is not a vigorous competitor, probably because of droughty site conditions. Montana limestones often weather into soils that are excessively well drained or otherwise make water less available to conifers than substrates derived from noncalcareous rocks. An example of this is Herbert Holdorf's (soil scientist, Lewis and Clark National Forest, Great Falls, Montana) observation that *Pinus contorta* occupies certain limestone formations in the Little Belts only where average annual precipitation is at least 30 inches. By contrast *Pinus contorta* grows in the same area on acidic rock substrates (granite, quartzite, etc.) where annual precipitation averages as little as 16 inches.

Stands are usually dominated by *Pseudotsuga* and often by apparently drought-resistant *Picea engelmannii* X *glauca* hybrids. *Pinus contorta* occurs sporadically and then only as a minor stand component. *Pinus flexilis* is a rather long-lived seral member of most *ABLA/CLPS* stands; it is diagnostic, since it is seldom found in other *Abies lasiocarpa* h.t.s. Sometimes *Pinus albicaulis* is also present, but it is common in much of the *Abies lasiocarpa* series (appendix B). (Differentiation of *Pinus flexilis* and *P. albicaulis* is discussed under Taxonomic Considerations in the Introduction.

Clematis pseudoalpina and *C. tenuiloba* (which intergrade) are usually present and are apparently confined to calcareous substrates. Like *Pinus flexilis,* they reach their upper elevational limits barely within the *Abies lasiocarpa* series, and are associated with the *Pseudotsuga* series below. *Spiraea betulifolia, Juniperus communis* and *Berberis repens* are the only frequently found shrubs. *Arnica cordifolia* and *Galium boreale* were present in all sample stands, and were accompanied by such dry-site forbs as *Aster conspicuus, Astragalus miser, Fragaria virginiana, Frasera speciosa, Valeriana dioica,* and *Zigadenus elegans.*

Soil.--All of our stands in the *ABLA/CLPS* h.t. were on calcareous parent materials (appendix D-1). Surface soils were silts to silty clay loams, ranging from slightly acidic to slightly basic. Gravel content was variable. Ground surfaces had little exposed rock or bare soil; duff depth averaged 4.2 cm.

Productivity/Management.--Forage values for both big game and domestic livestock appear to be low, although stands are often used as bedding areas by deer and elk. Domestic stock also bed and graze in this habitat type occasionally.

Timber productivity is low (appendix E-4). Site indexes for all species and maximum stand heights are consistently low (appendix E-1 and E-2). The steep, exposed slopes with shallow, fine-textured soils warrant special precautions to prevent erosion.

Other studies.--This habitat type has not been described elsewhere.

Abies lasiocarpa/Arnica cordifolia h.t.
(*ABLA/ARCO*; subalpine fir/heartleaf arnica)

Distribution.--*ABLA/ARCO* is a relatively cool, moist habitat type found in semi-arid mountains east of the Continental Divide, often on limestone substrates (Fig. 39). It is associated with benchlike uplands and north-facing slopes, and is found extensively in the southern portion of the Beaverhead National Forest (at 7,600 to 8,400 feet) as well as in the Little Belt Mountains (at 6,900 to 7,600 feet), where it is usually on limestone. *ABLA/ARCO* is seldom found elsewhere.

Warmer sites often support *ABLA/CARU, ABLA/CLPS* (on limestone), or *Festuca idahoensis*-dominated mountain parks. When this type occurs on limestone, the adjacent, topographically similar but noncalcareous sites usually support the *ABLA/VASC* h.t.

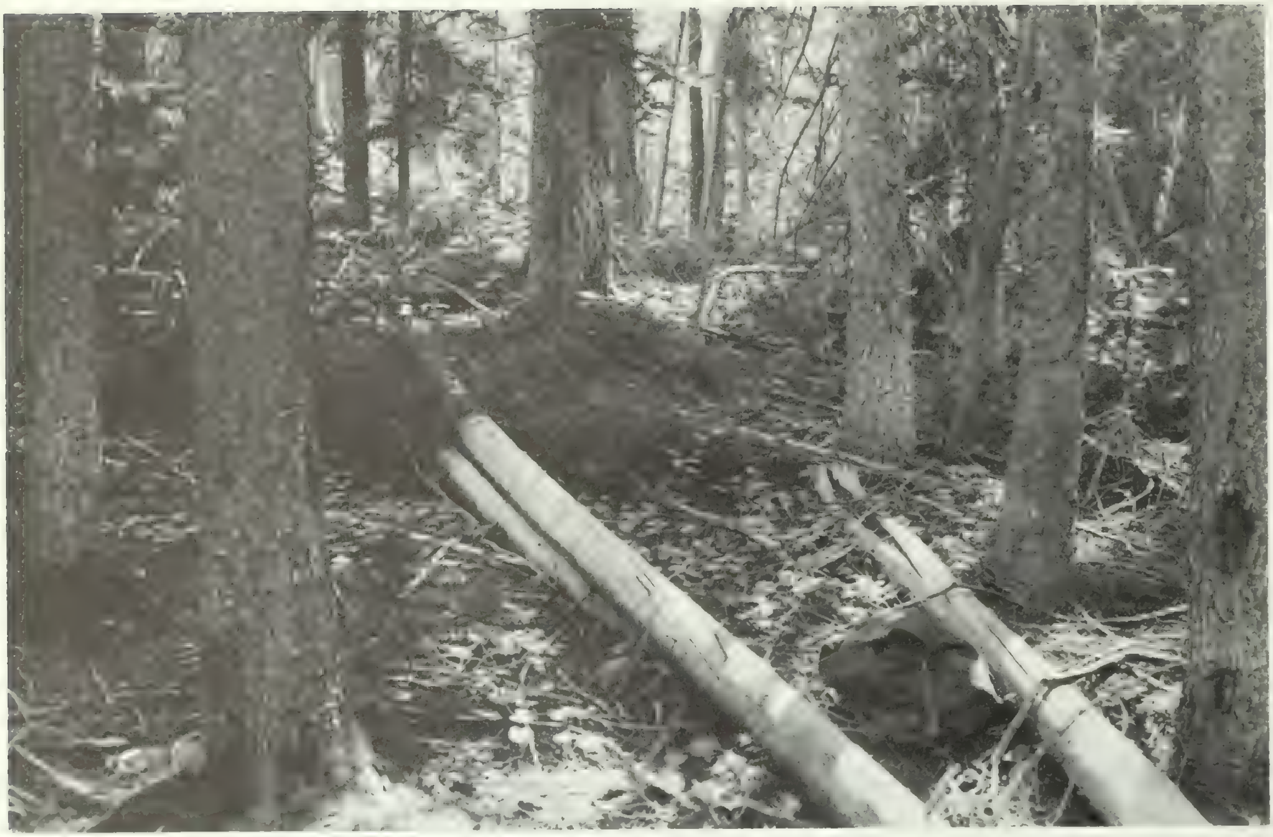


Figure 39.--Abies lasiocarpa/Arnica cordifolia *h.t. on a gentle north-facing slope (7,650 feet elev.) in the Centennial Mountains of southwestern Montana.* Pseudotsuga, Pinus contorta, *and* Picea *dominate the overstory of this 150- to 200-year-old stand; regeneration is mostly* Abies lasiocarpa. Arnica, Thalictrum, *and shrubby skirts of* Abies lasiocarpa *form the undergrowth.*

Vegetation.--Although *Abies lasiocarpa* is the apparent climax dominant, all but the oldest stands are dominated by *Pseudotsuga* or *Pinus contorta*. *Pinus contorta* is scarce in this habitat type in the Little Belts, where the stands are mostly on limestone. Conversely, *Picea* is a prominent seral component of most stands on limestone, but is less common elsewhere.

The forest canopy is dense and undergrowth is correspondingly rather sparse, consisting mostly of *Arnica cordifolia, Thalictrum occidentale, Osmorhiza chilensis, Pyrola secunda*, and small amounts of several other forb species. *Vaccinium scoparium* and *V. globulare* do poorly on calcareous substrates such as those characterizing the *ABLA/ARCO* h.t. in the Little Belts; but this does not explain their absence in the *ABLA/ARCO* h.t. in the Beaverhead National Forest on noncalcareous parent materials.

Soil.--Soils in the *ABLA/ARCO* h.t. were derived from a broad variety of parent materials (appendix D-1). Surface soils were acidic, mostly nongravelly loams to silty clay loams. Ground surfaces had little bare soil and rock exposed; duff depth averaged 3.9 cm.

Productivity/Management.--Timber productivity is moderate (appendix E-4). Old-growth individuals of *Pseudotsuga* may attain maximum diameters of 3 feet and heights of 90 to 95 feet. Sod-forming grasses are usually scarce and tree regeneration after logging is not retarded by a flush of undergrowth vegetation in most cases. Watershed values are relatively high. Forest stands received light use by deer, elk, and cattle, but forage production for big game and domestic livestock is very low.

Other studies.--*ABLA/ARCO* h.t. has also been described by Hoffman and Alexander (1976) in Wyoming and by Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) in east-central Idaho. Several stands apparently similar to this habitat type were sampled by Cooper (1975) in northwestern Wyoming (in his *Abies lasiocarpa/Thalictrum* h.t., *Arnica cordifolia* phase).

Abies lasiocarpa/Carex geyeri h.t.
(*ABLA/CAGE*; subalpine fir/elk sedge)

Distribution.--*ABLA/CAGE* is a minor habitat type in Montana that encompasses some of the driest sites in the *Abies lasiocarpa* series. It is apparently transitional to *PSME/CAGE* on still drier sites and to *ABLA/CARU* on slightly more moist sites. Sample stands were on southerly aspects between 6,600 and 7,700 feet elevation in the Gallatin National Forest (fig. 40) and from 6,700 to 7,100 feet in the Little Belt and Big Belt Mountains of central Montana.

Vegetation.--*Abies lasiocarpa* is the indicated climax. *Pseudotsuga* is the major, persistent seral dominant in the *PSME* phase, while *Pinus contorta* is usually the dominant seral tree in the *CAGE* phase. *Picea* is absent or at most widely scattered throughout the habitat type.

Undergrowth is dominated by *Carex geyeri; Calamagrostis rubescens* is poorly represented. Other characteristics of the undergrowth vary by phase of the habitat type.

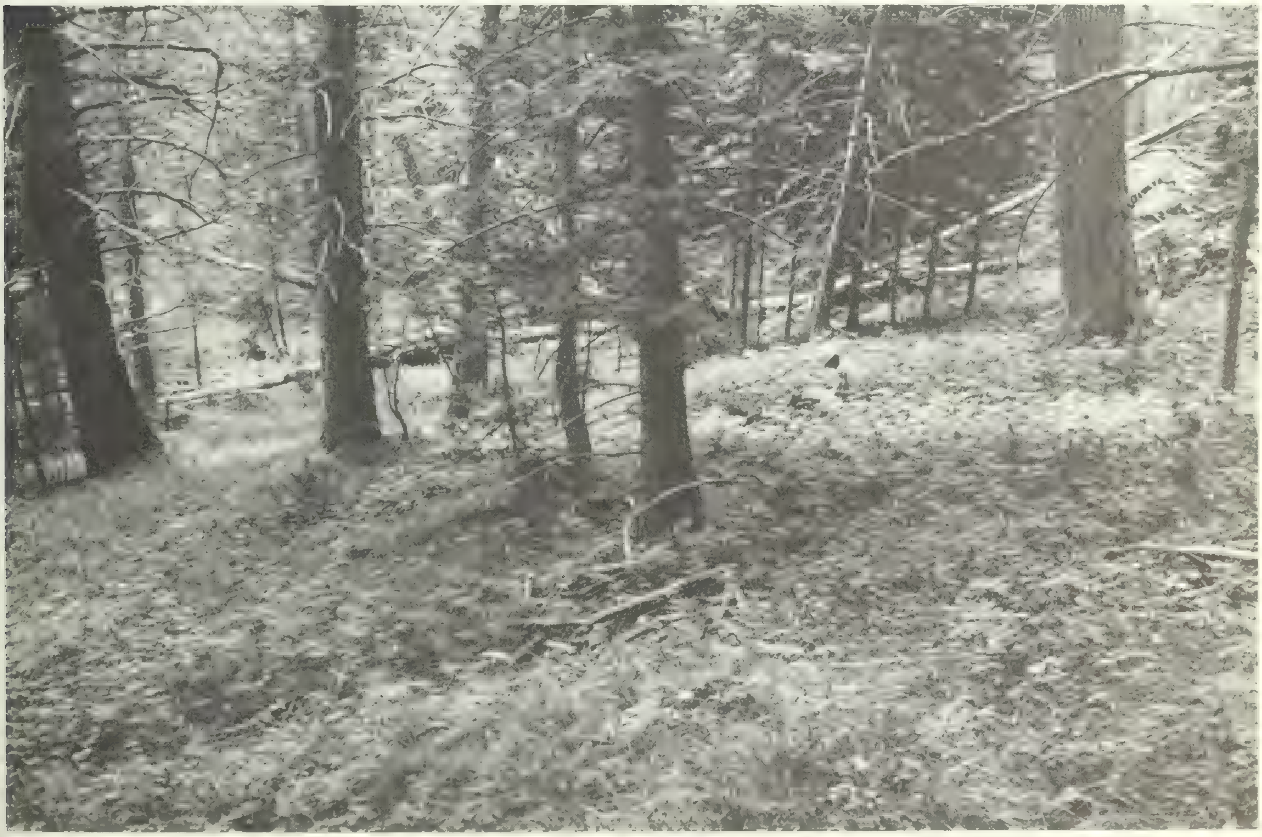


Figure 40.--Abies lasiocarpa/Carex geyeri *h.t. (*Pseudotsuga *phase) on a moderate northeastern exposure (7,250 feet elev.) south of Big Timber in south-central Montana.* Pseudotsuga *dominates the overstory, but* Abies lasiocarpa *makes up most of the regeneration.* Carex geyeri *and* Thalictrum *dominate the luxuriant undergrowth.*

Carex geyeri (CAGE) phase.--This phase represents the coldest conditions within the habitat type. Only three stands were sampled, two of them occupying limestone substrates atop broad ridges near 7,000 feet in the Castle and Little Belt Mountains. The other stand was found at 8,500 feet on noncalcareous rock in the Madison Range. *Abies lasiocarpa* and *Pinus contorta* were the only major tree components. Undergrowth was an almost pure *Carex geyeri* with low coverages of scattered forbs. *ABLA/VASC* was found on adjacent, more moist sites, and the *PSME* phase or the *ABLA/CARU* h.t. on warmer (lower-elevation) slopes.

Pseudotsuga menziesii (PSME) phase.--This is the warmer (lower elevation) phase of the type and it appears to be more common than the *CAGE* phase. It is transitional to the *ABLA/CARU* h.t. on more moist sites. Stands are dominated by *Pseudotsuga* as in *ABLA/CARU* but *Pinus contorta* and *Picea* are largely absent, reflecting the drier conditions. As in *ABLA/CARU*, the undergrowth is rich in forbs such as *Thalictrum occidentale*, *Osmorhiza chilensis*, *Smilacina racemosa*, and *Arnica cordifolia* or *A. latifolia*; however, *Calamagrostis rubescens* is poorly represented.

Soil.--Our stands were on a variety of parent materials (appendix D-1). Surface soils were primarily nongravelly loams to silts with reactions ranging from very acidic to slightly basic (on limestone). Ground surfaces had little rock or bare soil exposed; duff depth averaged greater than 5 cm.

Productivity/Management.--Timber productivity is low to moderate (appendix E-4). Choice of species is limited and varies by phase (appendix B); regeneration may be difficult to obtain because of the cold, dry conditions and perhaps the competition from *Carex geyeri* and associated species. Moderate summer use by deer and elk was evident in sample stands. Cattle use appeared to be limited to bedding in stands adjacent to meadows. Maintaining vegetative cover to prevent erosion may be especially important on these sites.

Other studies.--It appears that four of Cooper's (1975) stands in his *Abies lasiocarpa/Thalictrum* h.t., *Thalictrum* phase (from northwestern Wyoming) are comparable to our *PSME* phase. Some of Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) *ABLA/CAGE* h.t. stands (from central Idaho) are also similar to this phase. Robert Steele and others (1975) have described a *ABLA/CAGE* h.t., *CAGE* phase similar to ours in central Idaho. Also, our *CAGE* phase is similar in most respects to Cooper's (1975) *ABLA/CAGE* in the northwestern Wyoming vicinity. Wirsing (1973) also described *Abies lasiocarpa/Carex geyeri* h.t. in southern Wyoming.

UPPER SUBALPINE HABITAT TYPES

Abies lasiocarpa/Ribes montigenum h.t.
(*ABLA/RIMO*; subalpine fir/mountain gooseberry)

Distribution.--*ABLA/RIMO* is a minor habitat type found in upper subalpine areas near the southern boundary of Montana. The six stands sampled were found at 8,300 to 8,500 feet in the Pryor Mountains, at 8,300 to 9,000 feet in the Centennial Mountains, and at 8,900 feet in the southern Gravelly Range. All stands were on plateau-like sites or cool exposures above the limits of *Pseudotsuga* and apparently unfavorable for *Pinus contorta* (which was absent).

Vegetation.--Stands in the Pryor Mountains are jointly dominated by *Abies lasiocarpa* and apparent *Picea engelmannii* X *glauca* hybrids. *ABLA/RIMO* groves alternate with *Festuca idahoensis* grasslands which occupy more exposed sites where less snow accumulates. Stands in the Centennial and Gravelly Ranges were dominated by *Abies* and *Pinus albicaulis*, with lesser amounts of *Picea engelmannii*. They were bordered by the *ABLA/ARCO* h.t. at lower elevations and by *Festuca idahoensis*-dominated grasslands on drier exposures. Undergrowth was sparse in all stands, consisting of small, scattered clumps of *Ribes montigenum* and a few forbs such as *Arnica* spp.

Soil.--Soils were derived from a variety of parent materials (appendix D-1). Surface soils were very acidic nongravelly silts. Ground surfaces had little rock or bare soil exposed, and had deep duff (average 7.5 cm).

Productivity/Management.--Timber productivity is apparently low, based on limited data (appendix E-4). Forage production is very low, but deer, elk, and domestic livestock evidently use sites adjacent to mountain parks for resting and bedding.

Other studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) described this habitat type in central and southern Idaho, where it is dominated by *Pinus albicaulis* and *Abies lasiocarpa*. Pfister (1972a) described a similar habitat type in Utah beyond the range limits of *Pinus albicaulis* that is dominated by *Picea engelmannii* and *Abies lasiocarpa*.

Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium h.t.
(*ABLA-PIAL/VASC*; subalpine fir-whitebark pine/grouse whortleberry)

Distribution.--This very extensive habitat type constitutes most of the highest elevation forest belt in Montana east of the Continental Divide in all but the driest mountain ranges. It can generally be considered to be the east-side replacement for the *ABLA/LUHI* h.t. It is found on all exposures at elevations ranging from about 7,200 to 8,100 feet in central Montana, 8,000 to 8,800 feet in southwestern Montana, and 8,100 to 9,000 feet in south-central Montana (fig. 41).

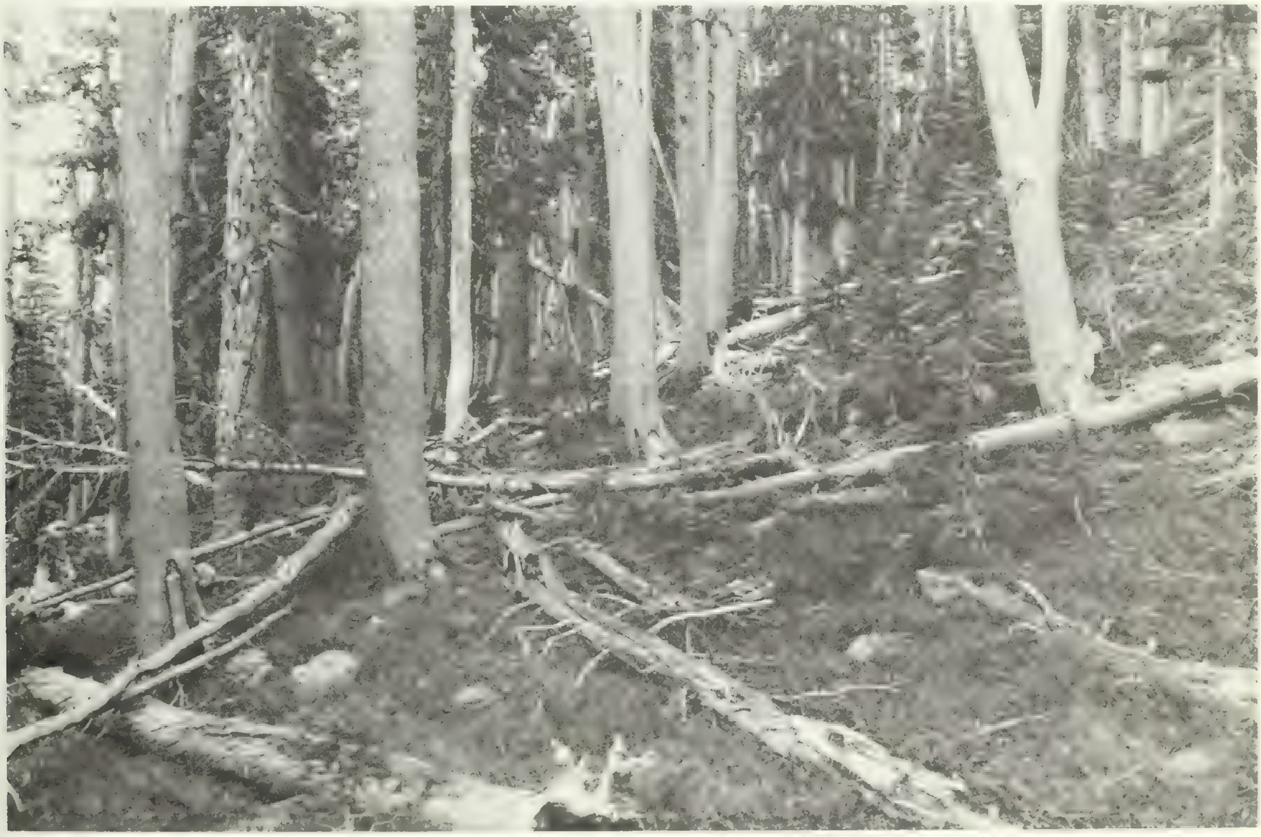


Figure 41.--Abies lasiocarpa-Pinus albicaulis/Vaccinium scoparium *h.t. on a northeast exposure (8,400 feet elev.) near Red Lodge in south-central Montana.* Pinus albicaulis *(up to 500 years of age) and* Picea engelmannii *dominate the overstory.* Abies lasiocarpa *regeneration is extensive, but this species does not grow as tall as* Pinus *or* Picea. *Undergrowth is almost entirely* Vaccinium scoparium.

ABLA-PIAL/VASC is usually bordered below by *ABLA/VASC*, but sometimes by *ABLA/XETE* or *ABLA/VAGL*. Drier sites may support subalpine grasslands or the *PIAL* h.t.s. Wetter sites support meadows or the *ABLA/CACA* h.t. It is bounded above by the *PIAL-ABLA* h.t.s.

Vegetation.--*Abies lasiocarpa* is the indicated climax dominant, but stands are also characterized by *Pinus albicaulis*, which is a long-lived, seral dominant approaching a "persistent" status on disturbed dry sites. *Picea engelmannii* is often a dominant, long-lived member of stands on moist sites. *Pinus contorta* is a major seral species at lower elevations.

Undergrowth in most stands is dominated by *Vaccinium scoparium*, although on drier sites or limestone substrates it sometimes gives way to *Carex geyeri*. *Xerophyllum* is often a codominant in moist stands near the Continental Divide. In some areas *Hieracium gracile* is largely restricted to this and higher habitat types. In such areas it may be useful as an indicator plant, but it does extend to somewhat lower elevations as an invader on roadsides, skid trails, etc. *Arnica latifolia* is the only other relatively consistent component of the undergrowth. *Phyllodoce* and *Ledum* often occur on moist sites. Like other upper subalpine types, *ABLA-PIAL/VASC* is characterized by a scarcity of the species that are so widely distributed in the forests below--e.g., *Spiraea betulifolia*, *Arctostaphylos uva-ursi*, *Calamagrostis rubescens*, *Berberis repens*, and *Pseudotsuga menziesii*.

Soil/Climate.--Soils in the *ABLA-PIAL/VASC* h.t. were derived from a wide variety of parent materials (appendix D-1). Surface soils were mainly gravelly loams to silts with acidic to very acidic reactions. Ground surfaces had moderate amounts of bare soil and rock exposed; duff depths averaged 4.4 cm.

This habitat type has a climate similar to that of *ABLA/LUHI*, except it is somewhat drier. Mean annual precipitation ranges from 25 to about 45 inches.

Productivity/Management.--Timber productivity is low (appendix E). Regenerating drier sites and those at higher elevations within the type will probably be difficult. Succession on disturbed sites will be slow and vegetation will be dominated by the same species found in old-growth stands. Managers should recognize the relatively high water yields and the importance of minimizing site disturbance because of slow vegetational recovery.

This type and adjacent meadows provide much of the summer range for elk, moose, mule deer, grizzly bears, and black bears in central and southern Montana.

Other studies.--Cooper (1975) described similar stands in his *ABLA/VASC* h.t., *Pinus albicaulis* phase. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) also had some similar stands in the upper part of their *ABLA/VASC* h.t. in central Idaho.

Abies lasiocarpa/Luzula hitchcockii h.t.
(*ABLA/LUHI*; subalpine fir/wood-rush)

Distribution.--*ABLA/LUHI* is the major upper subalpine forest habitat type from the Continental Divide westward in Montana. It forms a zone extending over about 700 feet in elevation between the *ABLA/XETE* or *ABLA/MEFE* h.t.s below, and the *PIAL-ABLA* or *LALY-ABLA* h.t.s above (table 6).

At its eastern limits, *ABLA/LUHI* covers high-elevation terrain contiguous with the Continental Divide from Glacier National Park south to Lewis and Clark Pass (northeast of Lincoln); it continues southward in the Flint Creek and Anaconda-Pintlar Ranges and in the Beaverhead Range almost to Lemhi Pass, west of Dillon. Farther east its counterpart *ABLA-PIAL/VASC* occupies a similar elevational zone, sometimes occurring adjacent to *ABLA/LUHI* on dry sites in west-central Montana.

Table 6.--*Distribution of* ABLA/LUHI *h.t. and* TSME/LUHI *h.t. sample stands by phase*

Geographic vicinity	VASC phase Elevation range	VASC phase Exposure	MEFE phase Elevation range	MEFE phase Exposure
	Feet		*Feet*	
Northern Idaho[1]	6,000-6,500	S-SE	5,750-6,500	W, N, E
Northwestern Montana	6,000-7,000	S-W	6,000-6,800	N-E
West-central Montana (and Sun River drainage)	7,100-8,400	All	6,800-7,600	N-E
Southwestern Montana	8,000-8,900	All	None	None

[1] From data in R. and J. Daubenmire (1968); ABLA/ or TSME/LUHI h.t., VASC phase stands--57 (Alberta), 127, 97, 128, and 61. ABLA/ or TSME/LUHI h.t., MEFE phase stands--58 (Alberta), 131, 135, 133, 46, 99, and 158.

Vegetation.--Abies lasiocarpa is the indicated climax. *Pinus albicaulis, Picea engelmannii,* and *Pinus contorta* are the principal seral species, although their relative importance varies by phase. Sites are above the limits of *Pseudotsuga, Larix occidentalis,* and *Pinus monticola.*

Luzula hitchcockii is present and usually well distributed throughout the stand; it is not confined to unusual microsites or disturbed areas. Some stands particularly near the eastern limits of the habitat type, have no *Luzula.* Nevertheless, they are assigned to the *MEFE* phase of this habitat type through use of the key (fig. 7) because *Pinus albicaulis* is well represented. Other major undergrowth species are *Vaccinium scoparium, Xerophyllum,* and *Arnica latifolia.*

Vaccinium scoparium (VASC) phase.--This phase is largely restricted to dry exposures (table 6) in northwestern Montana and northern Idaho. In west-central Montana and central Idaho (Robert Steele and others, 1975 preliminary draft, USDA Forest Service, Intermountain Station), however, it becomes more common, often occupying moist exposures.

Pinus albicaulis, a long-lived seral species, was present in all sample stands. *Picea engelmannii* is normally present, but is abundant only on especially moist sites. In west-central Montana *Pinus contorta* is a major component of seral stands near the lower limits of the phase.

Undergrowth is dominated by *Vaccinium scoparium, Xerophyllum tenax,* and *Arnica latifolia,* sometimes along with *Vaccinium globulare* or *Carex geyeri* on warm exposures. *Phyllodoce empetriformis* is often well represented on moist sites, and occasionally it forms the dominant undergrowth over broad areas on northerly exposures.

Menziesia ferruginea (MEFE) phase.--This phase is generally restricted to northerly exposures, and is most abundant in northwestern Montana (table 6). *Abies lasiocarpa* is a major component of most stands. *Picea engelmannii* is a long-lived, seral component in most stands, but is a major component only on the more moist sites--those having small coverages of species typically associated with the *ABLA/CACA* h.t., such as *Calamagrostis canadensis, Ledum glandulosum, Senecio triangularis, Dodecatheon jeffreyi, Veratrum viride,* or *Ligusticum canbyi.* Generally *Pinus albicaulis* is a minor stand component, while *Pinus contorta* is scarce. On sites having some soil development, *Larix lyallii* occasionally extends downward as a minor seral species; however, on sites consisting of coarse talus surrounded by this phase, *Larix lyallii* often forms pure groves, representing an edaphic climax. This situation has not been recognized as a separate habitat type because of the limited area involved.

Menziesia ferruginea, and occasionally *Rhododendron albiflorum*, dominate an undergrowth similar in other respects to that of the *VASC* phase.

Soil/Climate.--Soils in the *ABLA/LUHI* h.t. were derived from a variety of noncalcareous parent materials (appendix D-1). Surface soils were very acidic, gravelly loams to silts. Ground surfaces had little rock or bare soil exposed; duff depths averaged about 4.5 cm.

The climate is characterized by short, cool summers (mean July temperatures 55° to 59° F) with only a 2- to 3-month growing season. Snowfall and snow accumulations surpass those of most other habitat types in the northern Rockies. Snow covers the ground continuously from November 1 through June 15 in most years. Mean annual precipitation is 35 to 60 inches in Montana stands. Summer drought is less common here than in many other habitat types, but severe windstorms and blizzards limit height growth and damage trees on all but the most sheltered sites.

Productivity/Management.--Timber productivity is generally low, although a few moist sites in the *MEFE* phase show moderate productivity (appendix E-3). Stands of large *Picea* sometimes develop in basins and on sheltered slopes. Because the more productive sites are often associated with wet soils, logging road construction may present problems. Clearcutting may make regeneration of *Picea* difficult in these severe environments (Pfister 1972b), and create excessive ground water. Partial cuttings are likely to incur heavy blowdown losses, as in high-elevation *Picea* stands in Colorado (Alexander 1973). The generally low productivity and problems associated with management for timber production suggest minimal development on these sites, at least until successful methods are developed and proven.

Light summer use by mule deer, elk, and bear was observed. Domestic stock use and potential use is very low. This habitat type is a major source for summer streamflow in much of western Montana. Watershed protection and enhancement, as well as maintenanc of esthetic values for "high-county" recreational pursuits are of primary management importance.

Other studies.--Although R. and J. Daubenmire (1968) did not recognize this habitat type, their data indicate that 12 of their highest elevation *ABLA/XETE* and *ABLA/MEFE* stands would fit in *ABLA/LUHI* or *TSME/LUHI* h.t.s (table 6). These data and other observations suggest that *ABLA/LUHI* is probably well developed in parts of northern Idaho. Also, it has been described in central Idaho and in the Nezperce National Forest by Robe Steele and others (1975 and 1976 preliminary drafts, USDA Forest Service, Intermountain Station). In south-central British Columbia, McLean (1970) described an *Abies lasiocarpa/Vaccinium scoparium* h.t., *Phyllodoce empetriformis* phase that contains *Luzula* and is apparently similar to our *ABLA/LUHI* h.t., *VASC* phase.

Tsuga mertensiana/Luzula hitchcockii h.t.
(*TSME/LUHI*; mountain hemlock/wood-rush)

Distribution.--This habitat type is found along and adjacent to the Montana-Idaho Divide from Lolo Pass to the Cabinet Gorge between about 6,000 and 6,500 feet in elevation. Although it covers only a small area in Montana, it is evidently much more extensive immediately to the west in northern Idaho. More than half of R. and J. Daubenmire's stands that have *Luzula* spp. (apparently *Luzula hitchcockii*) have *Tsuga mertensiana* as a climax dominant; thus, these stands are comparable to our *TSME/LUHI* h.t.

Vegetation.--This habitat type has vegetation similar to the *ABLA/LUHI* h.t. except for the addition of *Tsuga mertensiana* as a major climax component. *Tsuga* is apparently the sole climax dominant in some stands, but forms a coclimax with *Abies lasiocarpa* in others. Most of R. and J. Daubenmire's apparent *TSME/LUHI* sample stands had only minor amounts of tree species other than *Tsuga* and *Abies*.

Vaccinium scoparium (VASC) phase.--This phase is associated with exposed ridgetops and southerly exposures. Undergrowth is dominated by *Xerophyllum tenax* and *Vaccinium scoparium*. It is generally comparable to the *ABLA/LUHI* h.t., *VASC* phase (table 6).

Menziesia ferruginea (MEFE) phase.--This phase is associated with sheltered slopes and cool aspects. It is generally comparable to the *ABLA/LUHI* h.t., *MEFE* phase (table 6).

Soil/Climate.--Soils appear similar to those described for the *ABLA/LUHI* h.t. (appendix D-1).

The type occupies the most maritime of the high subalpine environments in the Northern Rockies. Annual precipitation, snowfall, and cloudiness tend to be greater than in the *ABLA/LUHI* h.t.

Productivity/Management.--This is similar to the *ABLA/LUHI* h.t., based on limited data.

Other studies.--*TSME/LUHI* h.t. has not been described in other studies. Comparable stands from northern Idaho were classified under the *TSME/XETE* and *TSME/MEFE* h.t.s by R. and J. Daubenmire (1968).

TIMBERLINE HABITAT TYPES

A general discussion of characteristics and management implications common to all of the timberline habitat types is presented on pages 79-81.

Pinus albicaulis-Abies lasiocarpa h.t.s
(*PIAL-ABLA*; whitebark pine-subalpine fir)

Distribution.--*PIAL-ABLA* h.t.s. include most timberline sites in Montana and the Northern Rockies. Our *PIAL-ABLA* h.t.s. category and the other timberline habitat types encompass more variation in vegetational composition and tree life-forms than the forest habitat types found at lower elevations. However, there seems to be little need at this time to subdivide the complex undergrowth.

Vegetation.--*Pinus albicaulis*, *Abies lasiocarpa*, and *Picea engelmannii* occur in varying amounts. *Abies lasiocarpa* is generally not vigorous in these types; it is often stunted, wind-deformed, and shrublike (fig. 42). Saplings grow slowly, and on many sites this species reproduces largely through layering of lower branches. The superior hardiness of *Pinus albicaulis* and *Picea* allows them to coexist with the more shade-tolerant *Abies* at timberline. Often *Abies* is capable of achieving tree size only in the lee of the protective canopy of a large *Pinus* or *Picea*.

Undergrowth is quite variable, but *Vaccinium scoparium*, *Arnica latifolia*, and *Hieracium gracile* are present in most stands. *Luzula hitchcockii* and *Xerophyllum* are also prevalent in stands west of the Continental Divide. Mountain heath--*Phyllodoce empetriformis*, *P. glanduliflora*, and *Cassiope mertensiana*--is common in these habitat types on moist sites, especially west of the Continental Divide. On dry sites, especially east of the Continental Divide, the undergrowth is often dominated by *Juncus parryi*, *Carex rossii*, *Festuca idahoensis (F. ovina)*, or *Arenaria congesta*.

Soil.--Soils in our sample stands were derived primarily from sandstone and argillite parent materials (appendix D-1). Surface soils were acidic to very acidic, gravelly loams to silts. Ground surfaces averaged 13 percent rock and 6 percent bare soil exposed; duff depth averaged only 2.8 cm.

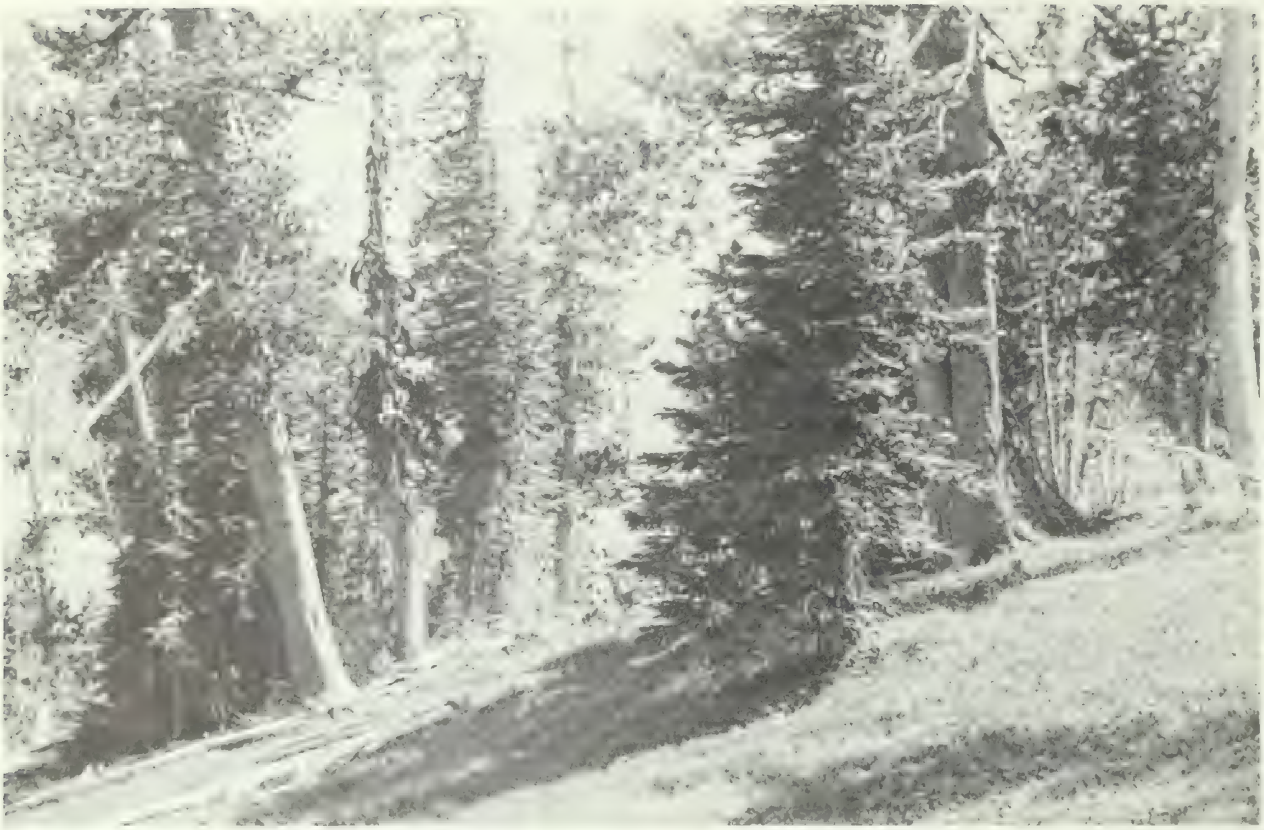


Figure 42.--A Pinus albicaulis-Abies lasiocarpa *h.t. on an east exposure (8,000 feet elev.) on limestone substrate west of Augusta in central Montana.* Pinus albicaulis *and scattered* Picea *form the overstory; layered saplings of* Abies lasiocarpa *dominate the regeneration layer, but maximum height attained by this species is only 20 feet. Undergrowth is primarily* Vaccinium scoparium.

Other studies.--A *Pinus albicaulis-Abies lasiocarpa* association in eastern Washington and northern Idaho was described briefly by R. and J. Daubenmire (1968) as being confined to small areas atop the highest ridges and peaks, where it forms a belt of severely stunted "wind timber." By contrast, the *PIAL-ABLA* h.t.s are much better developed in Montana, and at least 25 mountain ranges support alpine tundra above timberline. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) have described *PIAL-ABLA* h.t.s similar to ours in central Idaho, except that *Picea* is generally absent.

Larix lyallii-Abies lasiocarpa h.t.s
(*LALY-ABLA*; alpine larch-subalpine fir)

Distribution.--*LALY-ABLA* h.t.s are prevalent on cool exposures in many timberline areas west of the Continental Divide in Montana. (*PIAL-ABLA* h.t.s usually occupy the adjacent warmer exposures.) *LALY-ABLA* h.t.s are best developed on granitic and quartzite substrates where there has been little if any soil development; they occur only on limited areas of finer sedimentary rock (i.e., argillites of the Belt Series), and apparently do not occur on limestone (Arno 1970). They are most extensive at the highest elevations of the Bitterroot, Anaconda-Pintlar, and Cabinet Ranges, but are also found atop the Whitefish, Swan, south Mission, Sapphire, and Flint Creek Ranges, as well as in scattered areas of Glacier National Park and the headwaters of the Teton and Sun Rivers (Arno and Habeck 1972).

Vegetation.--*Larix lyallii* is a long-lived dominant on these sites; it is accompanied by variable amounts of *Pinus albicaulis, Abies lasiocarpa,* and *Picea engelmannii.* At the highest elevations of the type, *Larix lyallii* often forms pure groves of erect trees on sites that are above the "tree limits" of the evergreen conifers (fig. 43). Undergrowth is usually dominated by combinations of *Phyllodoce empetriformis, Luzula hitchcockii, Vaccinium scoparium,* and severely stunted or shrublike *Abies lasiocarpa* (Arno and Habeck 1972).

Soil.--Soils were derived primarily from granite and quartzite parent materials, but occasionally from noncalcareous shale and argillite (Arno 1970). Surface soils were very gravelly loams usually ranging from 3.9 to 5.7 in pH. Ground surfaces had large amounts of rock but relatively little mineral soil exposed.

Other studies.--According to Arno and Habeck (1972) *Larix lyallii* is closely restricted to the outer fringe of the maritime mountain environments throughout its distribution in the northern United States and southern Canadian Rockies and along the eastern slope of the northern Cascades. Moreover, *Larix lyallii* has a nearly constant association with cool aspects and heavily glaciated acidic rocky sites at or near climatic timberline. A more detailed description of these sites is available in Arno and Habeck (1972).

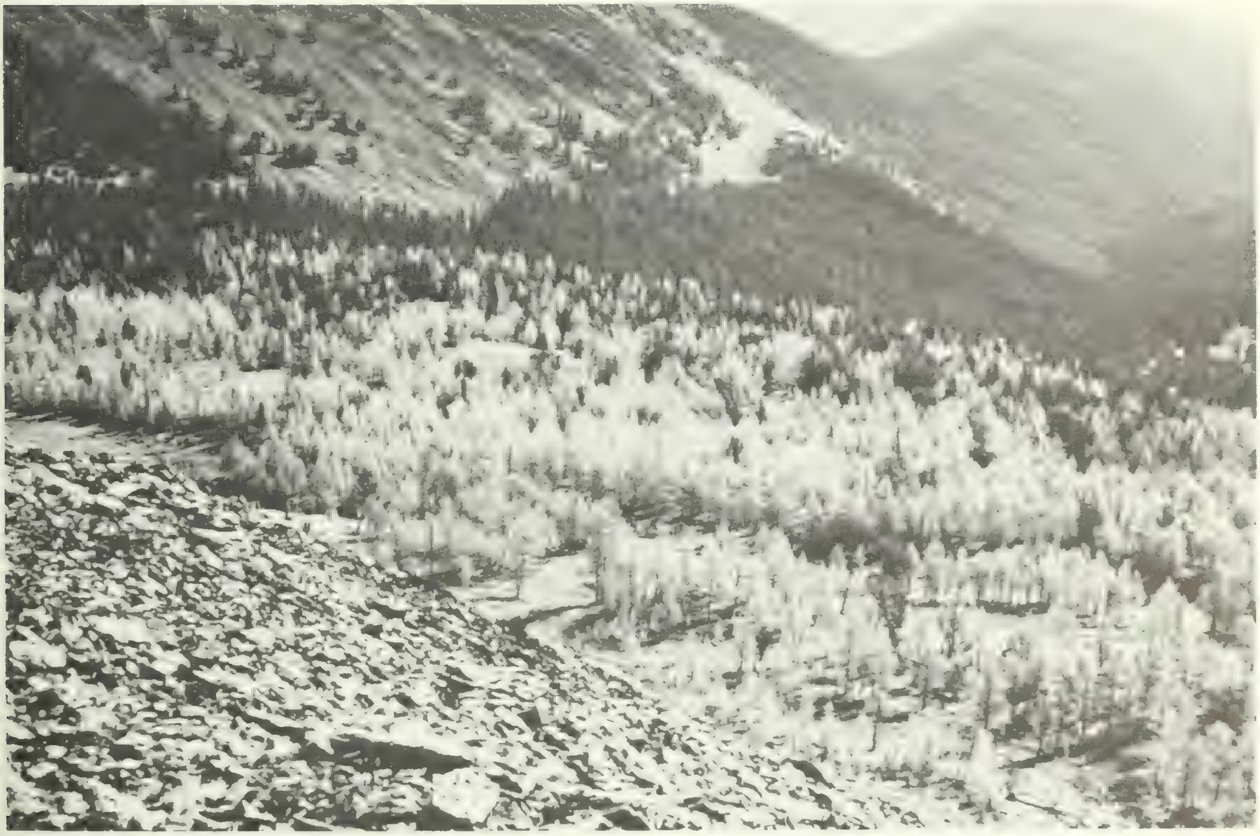


Figure 43.--A Larix lyallii-Abies lasiocarpa *h.t. at the head of a drainage (8,700 to 9,000 feet elev.) in the Anaconda-Pintlar Range north of Wisdom.* Larix lyallii *(turning color) and scattered* Pinus albicaulis *dominate, with stunted* Abies lasiocarpa *beneath them.* Vaccinium scoparium *and* Luzula hitchcockii *are the principal undergrowth plants.*

Pinus albicaulis h.t.s
(*PIAL*; whitebark pine)

Distribution.--*PIAL* h.t.s are rather common atop the drier mountain ranges east of the Continental Divide on sites apparently too dry for *Abies lasiocarpa* and near or above the cold limits of *Pseudotsuga* and *Pinus flexilis*. These types occur from the climatic timberline downward on exposed ridges and south slopes. Thus, they do not always represent cold timberline conditions, but sometimes occur where tree growth is limited by drought within the upper subalpine zone. Below that point, *Pseudotsuga* becomes the indicated climax (*Pseudotsuga* series), although *Pinus albicaulis* may remain well represented as a persistent seral species.

Vegetation.--*Pinus albicaulis* is the only tree species found in appreciable quantity in the *PIAL* h.t.s (fig. 44). Other timberline conifers apparently require more moisture.

Undergrowth is variable, ranging from essentially pure *Vaccinium scoparium* on the highest, least-droughty sites, to *Carex geyeri* (or occasionally *Juncus parryi*) on drier sites, and ultimately to *Festuca idahoensis* (*F. ovina*) and dry-site forbs on the most arid sites capable of supporting trees. Adjacent drier sites are occupied by subalpine grasslands, while more moist sites (e.g., northerly exposures or less windy exposures) usually support the *PIAL-ABLA* or *ABLA-PIAL/VASC* h.t.s.

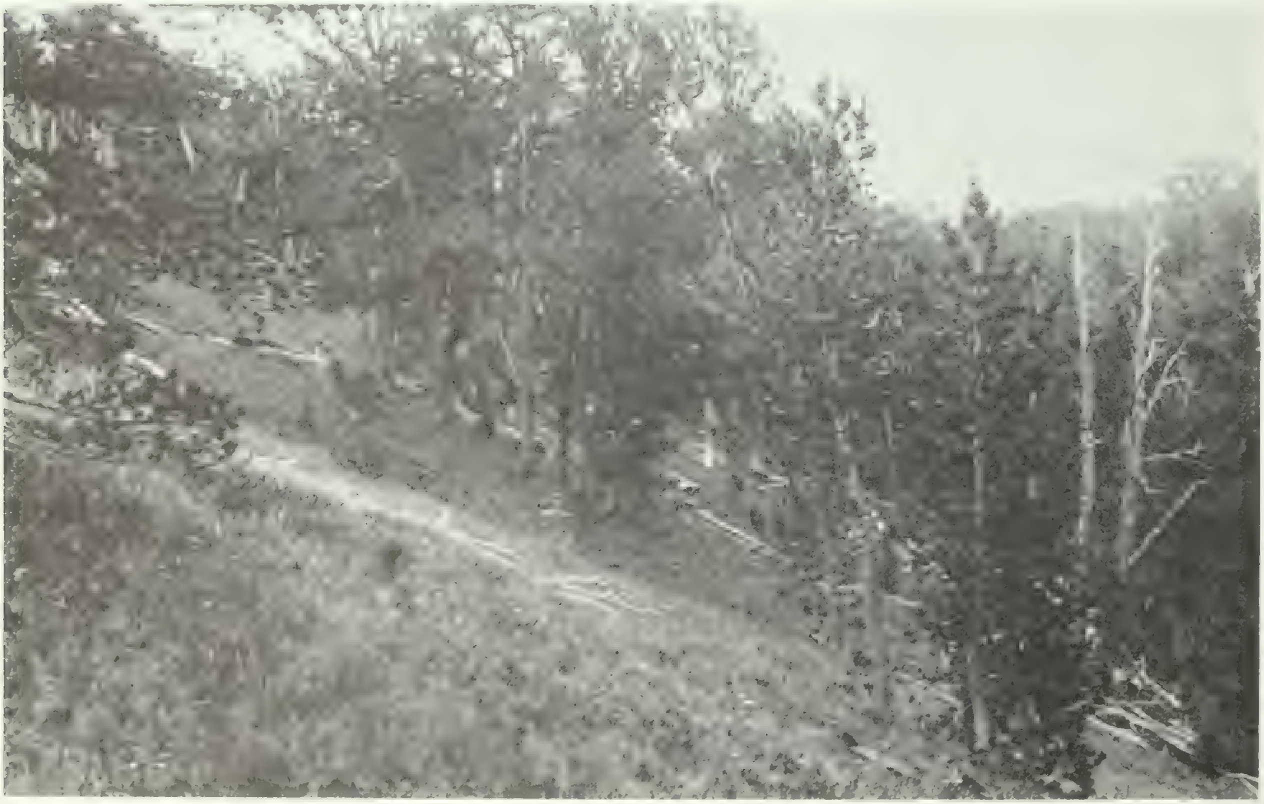


Figure 44.--A Pinus albicaulis *h.t. on a steep southwest exposure (7,900 feet elev.) on limestone substrate in the Little Belt Mountains of central Montana. The stand is composed of many-aged* Pinus albicaulis *with widely scattered, stunted saplings of* Pseudotsuga *and* Abies lasiocarpa. *Undergrowth is an extensive mixture of dry-meadow forbs and grasses.*

Soil.--Our stands were on a variety of parent materials (appendix D-1). Surface soils were gravelly silt loams and silts ranging from slightly basic (on calcareous substrates) to slightly acidic. Ground surfaces had little rock or bare soil exposed; duff depths averaged only 2.7 cm.

Other studies.--Weaver and Dale (1974) described a *Pinus albicaulis/Vaccinium scoparium* association in central Montana which is similar to the coldest and least droughty of our *PIAL* h.t.s. In northwestern Wyoming, Cooper (1975) also described a *Pinus albicaulis/Vaccinium scoparium* h.t. in addition to a *Pinus albicaulis/Carex geyeri* h.t., *Pinus albicaulis* phase; both of these can be considered subdivisions of our *PIAL* h.t.s. However, none of these are similar to the *Festuca* and dry-forb dominated undergrowth situations we found in Montana. Reed (1976) designated a *Pinus albicaulis/ Vaccinium scoparium* h.t. in the Wind River Mountains of Wyoming. However, some of his stands did not contain *V. scoparium*. We have followed the method of Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station); they recognized *PIAL* h.t.s. in central Idaho and used the plural to denote their diversity, but did not formally subdivide the category.

Pinus contorta Series

Distribution.--This series consists of essentially pure stands of *Pinus contorta* in which there is insufficient evidence to indicate that other species constitute the potential climax. These stands occur on extensive areas in Montana, primarily at elevations of 5,000 to 7,500 feet east of the Continental Divide. They are typically located on well-drained upland sites with gentle topography. This series is similar environmentally to the colder part of the *Pseudotsuga* series, the drier part of the *Picea* series, and the warm, dry part of the *Abies lasiocarpa* series.

Vegetation.--The almost exclusive dominance of *Pinus contorta* may be due to these factors:

1. Historic, repeated wildfires over large areas may eliminate seed sources of potential shade-tolerant competitors.

2. Light ground fires may remove invading shade-tolerant competitors from the understory.

3. Dense stands may prevent regeneration of all conifers for up to 200 years in the absence of disturbance or stand deterioration.

4. Sites may be unfavorable for the establishment of other conifers. (In Montana, the best example of this situation is the *PICO/PUTR* h.t.)

Initially we selected 82 stands in which *Pinus contorta* was the nearly exclusive dominant. About half of these stands had enough other conifers *(Pseudotsuga, Picea,* and *Abies lasiocarpa)* to suggest eventual replacement of *Pinus contorta*; thus, they were also analyzed within that indicated series. After analyzing the 82 stands, we recognized 12 groups of communities. One group had definite evidence of climax potential for *Pinus contorta*, unique undergrowth, and unique environmental features; it was designated as the *PICO/PUTR* h.t. (fig. 45). Seven groups appeared to represent seral communities of other habitat types; these stands were removed from the *Pinus contorta* series and placed in their appropriate habitat types. The remaining four groups had undergrowth similar to that of habitat types in other series, but were defined as community types (c.t.) in the *Pinus contorta* series to indicate that *Pinus contorta* could possibly be the potential climax dominant (fig. 46). Another reason for recognizing these four groups as distinct community types was to facilitate field identification. Also, from a practical standpoint, it appears most reasonable to manage them as if *Pinus contorta* were the potential climax dominant.

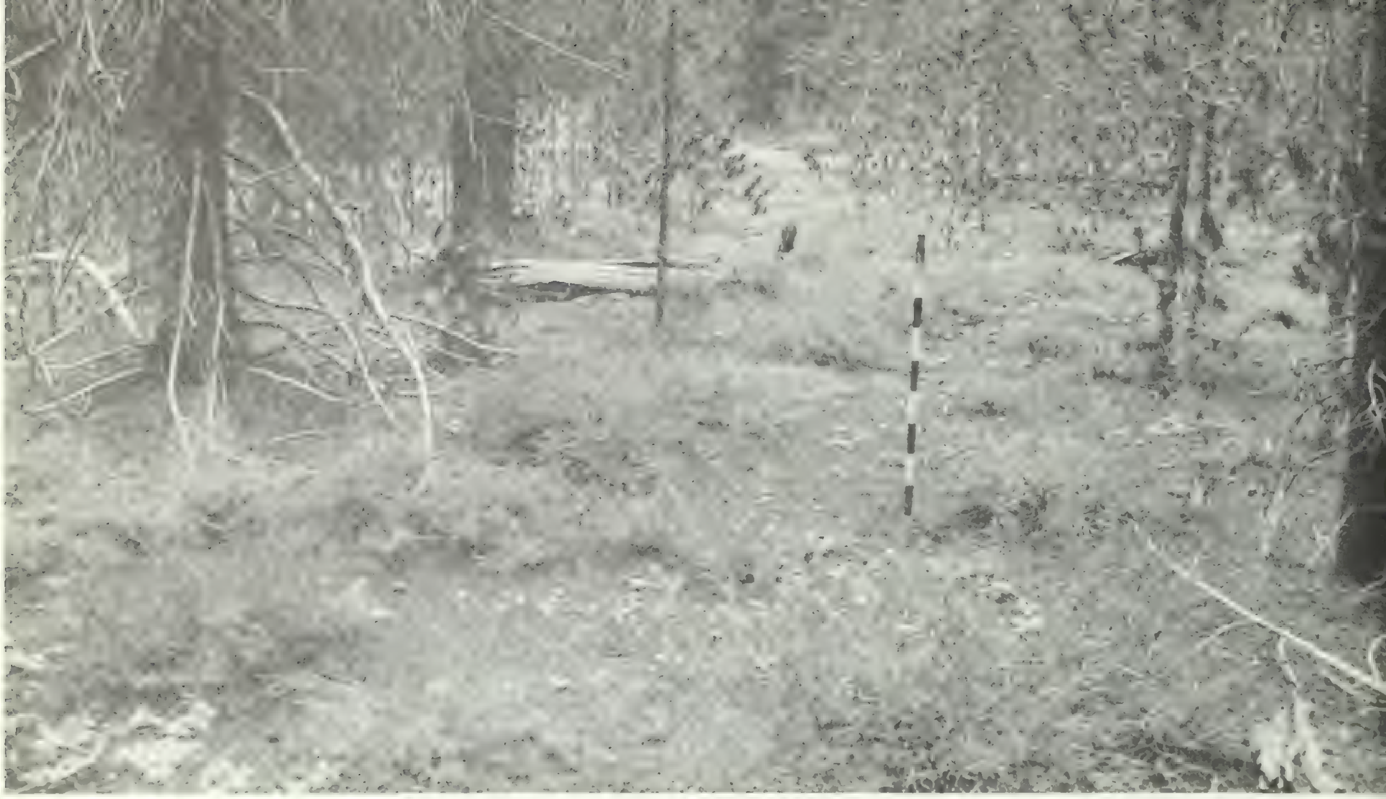
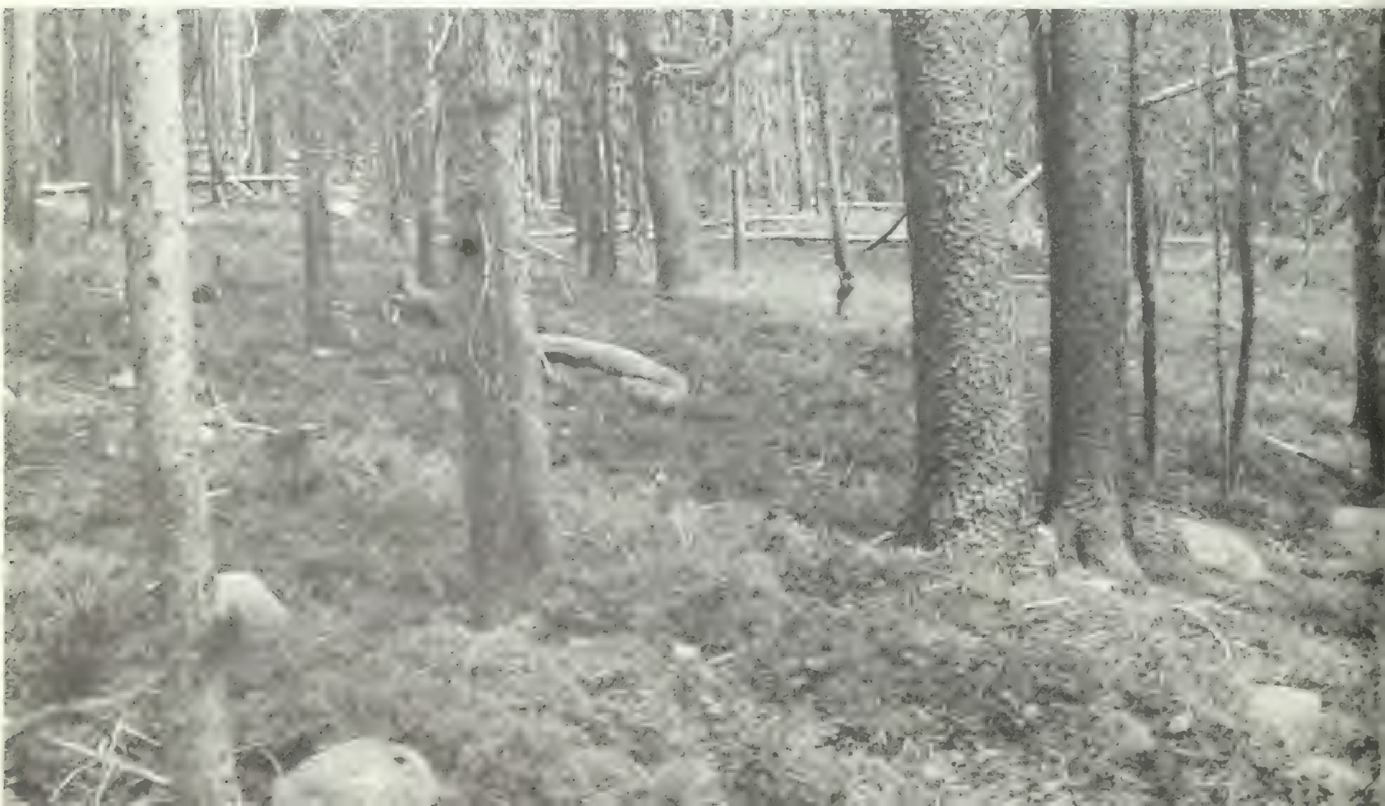


Figure 45.--Pinus contorta/Purshia tridentata *h.t. on flat ground (6,600 feet elev.) at West Yellowstone, Montana.* Pinus contorta *is the only tree species and is regenerating successfully in undisturbed stands.* Purshia *is the dominant undergrowth plant.*

Figure 46.--Pinus contorta/Vaccinium scoparium *community type on a gentle southwest-facing slope (7,000 feet elev.) southwest of Helena.* Pinus contorta *is virtually the only tree species and is regenerating successfully; however, there is also widely scattered regeneration of* Abies lasiocarpa *and* Picea. Vaccinium scoparium *forms the principal undergrowth.*



In field identification it is important to remember that all *Pinus contorta*-dominated stands do not belong in this series. Stands with good representations of shade-tolerant competitors are clearly early successional stages and should be classified as habitat types in other series. Dense, stagnated, young stands may not allow regeneration of any species. By observing nearby seed sources and comparing these sites with similar sites supporting less dense stands, one can determine whether the stand represents a seral stage within another series or a possible *Pinus contorta* climax.

Soil/Climate.--Soils throughout the *Pinus contorta* series are derived from a wide variety of noncalcareous parent materials (appendix D-1). Surface soils range from acidic to very acidic, and are generally gravelly with a broad range of textures from coarse loamy sands to silts. Ground surfaces have small amounts of rock or bare soil exposed, and moderate duff accumulations. The only known weather station within the *Pinus contorta* series in Montana is West Yellowstone (appendix D-2).

Productivity/Management.--Timber productivity is low to moderate (appendix E). Based upon present evidence, *Pinus contorta* is the only tree species that can be managed successfully. Monoculture seems inevitable, but flexibility is available in silvicultural practices due to lack of competing conifers. Stands show evidence of light use (primarily spring to fall) by mule deer, elk, and occasionally moose. Water yield should be moderately high and subject to management by manipulation of vegetation. The gentle topography is well suited to many management activities; however, the esthetic appeal of these forests may be limited somewhat by their monotonous character.

Other studies.--Pfister and Daubenmire (1975) listed the current references to plant communities in the northwestern United States which refer to *Pinus contorta* as climax. The *Pinus contorta/Purshia tridentata* communities described by Youngberg and Dahms (1970) in Oregon appear similar to the *PICO/PUTR* h.t. of southern Montana. Additionally, the *Pinus contorta/Vaccinium uliginosum* community listed by Franklin and Dyrness (1973)--in which *Vaccinium caespitosum* is a characteristic species--may be related to our *Pinus contorta/Vaccinium caespitosum* community type. Moir (1969) also described a zone in Colorado where *Pinus contorta* is either climax or in a prolonged seral stage. Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) described one *Pinus contorta* habitat type and several community types in central Idaho. Cooper (1975) described a *Pinus contorta* habitat type, as well as almost pure *Pinus contorta* stands within two other habitat types, in the northwest Wyoming vicinity. Hoffman and Alexander (1976) and Reed (1976) described a total of three *Pinus contorta* h.t.s in Wyoming.

Pinus contorta/Purshia tridentata h.t.
(*PICO/PUTR;* lodgepole pine/bitterbrush)

Distribution.--This habitat type has been observed only on obsidian-sand benchland of alluvial origin in the vicinity of West Yellowstone, Montana. It covers an area of perhaps 100 square miles at an elevation of approximately 6,600 feet.

At one point a rhyolite monolith (Horse Butte) rises about 300 feet in elevation from within this area; it supports an *ABLA/CARU* h.t. on northerly exposures, grassland on south exposures, and distinctive *Populus tremuloides-Picea* groves on the small area of flat terrain. Growth rates of *Abies lasiocarpa, Picea,* and *Pseudotsuga menziesii* are excellent on Horse Butte, but these species do not invade the adjacent obsidian-sand benchland. Because summer frosts are frequent at West Yellowstone (appendix D-2), these benchland sites are probably too frosty for *Pseudotsuga* and too dry (excessively well drained) for *Abies* and *Picea.*

Vegetation.--Stands are moderately open with numerous age classes (apparently all aged) of self-replacing *Pinus contorta.*

The undergrowth is sparse, with *Purshia tridentata* the most prominent plant. Scattered patches of *Arctostaphylos uva-ursi* are usually found; forbs include *Phlox multiflora, Antennaria microphylla, Lupinus* spp., and *Crepis acuminata;* graminoids include *Carex rossii, Sitanion hystrix, Danthonia intermedia, Poa nervosa,* and *Agropyron spicatum. Purshia* is locally scarce on recently burned land, but its seedlings usually reinvade within a few years.

Soil.--Soils in the *PICO/PUTR* h.t. were derived from obsidian-sand alluvial outwash. Surface soils are coarse sandy loams with acidic reactions. Ground surfaces had no bare soil or surface rock exposed; litter depth ranged from 2 to 5 cm. Cooper (1975) observed that the obsidian-sand outwash is often underlain by lake silts; he provides a more detailed description of soil characterisitcs for the same sampling area.

Productivity/Management.--Timber productivity is low (appendix E-4) because of low site indexes and stockability limitations. Cone serotiny (closed cones) averaged 40 percent in our three sample stands. In an earlier study, Lotan (1967) found 38 percent serotiny in the same area, compared with 58 percent serotiny in an adjacent upland stand on a different habitat type. The open cone habit aids development of all-aged stands, while cone serotiny insures stand replacement following an intense wildfire.

Stermitz and others (1974) studied the relationship of soil characteristics to *Pinus contorta* regeneration in the West Yellowstone area *(PICO/PUTR* h.t.). They found a strong positive correlation between seedling survival and amount of fine material (silt plus clay) in the soil.

In addition to being hampered by coarse (droughty) soils, regeneration may be retarded by frost damage, since natural regeneration was observed to be more successful in shaded than in cleared areas.

Mule deer and moose appear to use the type heavily, at least during summer.

Other studies.--Cooper (1975) sampled seven stands (compared with our three) in the West Yellowstone area, and provided a detailed description of this habitat type. Youngberg and Dahms (1970) described a very similar climax community type on well-drained pumice soils in frost pockets in central Oregon.

Pinus contorta/Vaccinium caespitosum community type
(PICO/VACA c.t.; lodgepole pine/dwarf huckleberry)

Distribution.--The *PICO/VACA* c.t. occurs mostly east of the Continental Divide on benches and gentle slopes. Stands were most commonly found on the Beaverhead and Lewis and Clark National Forests, between 6,200 and 7,200 feet in elevation. A few stands were sampled west of the Divide near Kalispell, Lincoln, and Philipsburg at 4,800 to 6,500 feet.

Vegetation.--Most stands showed evidence of possible succession to the *ABLA/VACA* h.t., which is also normally dominated by *Pinus contorta.* A few stands found on drier sites may be on a *PSME/VACA* h.t., and one stand located on coarse granitic sand in the Wise River drainage (Beaverhead National Forest) appeared to be *Pinus contorta* climax. The latter stand was apparently too frosty for *Pseudotsuga* and too dry for *Abies lasiocarpa* and *Picea.* (Note that seral stands dominated by *Pinus contorta*, but having an understory in which shade-tolerant conifers are well represented, are referred to as a successional stage of another habitat type.)

Vaccinium caespitosum is normally well represented and codominant with *Calamagrostis rubescens* in the undergrowth. *Vaccinium scoparium* and *Arctostaphylos uva-ursi* are often well represented and *Linnaea borealis* is often present on moist sites.

Soil.--Our stands were on a variety of noncalcareous parent materials (appendix D-1). Surface soils ranged from gravelly to nongravelly, from sandy loams to silts, and from very acidic to acidic. Ground surfaces had virtually no rock or mineral soil exposed; duff depths averaged 4.8 cm.

Productivity/Management.--Timber productivity is moderate (appendix E-4). *Pinus contorta* is the only species that can be managed with assurance of success. Planting of other conifers should be conducted only on an experimental basis. Other management implications are similar to those for the *ABLA/VACA* h.t. or the *PSME/VACA* h.t.s east of the Continental Divide.

Other studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) also recognized this community type in central Idaho.

Pinus contorta/Linnaea borealis community type
(*PICO/LIBO* c.t.; lodgepole pine/twinflower)

Distribution.--*PICO/LIBO* c.t. is common near and east of the Continental Divide, mostly between elevations of 5,600 and 7,200 feet; it is infrequently found farther west. Sites are on benchlands or north-facing midslopes.

Vegetation.--Seven of our sample stands were possibly successional stages of the *ABLA/LIBO* h.t., *VASC* phase. Three stands might have been attributed to the *PICEA/LIBO* h.t. and one to the *PSME/LIBO* h.t. Six stands had no indication of climax other than *Pinus contorta*. (Note that seral stands dominated by *Pinus contorta*, but having an understory in which shade-tolerant conifers are well represented, are referred to as a successional stage of another habitat type.)

Undergrowth in the *PICO/LIBO* c.t. is dominated by various combinations of *Vaccinium globulare, V. scoparium,* and *Calamagrostis rubescens,* apparently reflecting the adjacent habitat types; however, *Linnaea borealis* is common throughout.

Soil.--Soils were derived from a variety of noncalcareous parent materials. Surface soils were acidic to very acidic sandy loams to silts. Gravel content averaged 21 percent. Ground surfaces had little surface rock and no bare soil exposed; duff depth averaged greater than 6 cm.

Productivity/Management.--Timber productivity is moderate (appendix E). *Pinus contorta* is the only species that can be managed with assurance of success. Planting of other conifers should be conducted only on an experimental basis. Deer, elk, and moose evidently use these areas lightly from spring to fall.

Other studies.--In central Idaho, Robert Steele and others (1975) found some *Pinus contorta*-dominated communities with *Linnaea* in the undergrowth, but they attributed these to their *ABLA/LIBO* h.t.

Pinus contorta/Vaccinium scoparium community type
(*PICO/VASC* c.t.; lodgepole pine/grouse whortleberry)

Distribution.--*PICO/VASC* c.t. occurs on relatively cold, dry sites on all exposures, mostly near and east of the Continental Divide. Most sample stands are found on gentle middle and upper slopes or broad ridgetops at 6,000 to 7,700 feet.

Vegetation.--Stands are typically even-aged and dominated almost exclusively by *Pinus contorta*. Some of the more open stands have *Pinus contorta* regeneration with widely scattered shade-tolerant conifers. Eight stands at higher elevations (mostly over 7,000 feet) were similar to the *ABLA/VASC* h.t., *VASC* phase, except for scarcity of *Abies lasiocarpa*. In the remaining 12 stands, at 5,800 to 7,100 feet, *Calamagrostis* *rubescens* and *Arctostaphylos* were common. Four of these were suggestive of *ABLA/VASC* h.t., *CARU* phase; four were indicative of a *Pseudotsuga* climax; and four were essentially pure *Pinus contorta*. The presence of limited amounts of *Pseudotsuga* does not preclude the possibility that the stands could also support *Picea* or *Abies* at climax. (Note that seral stands dominated by *Pinus contorta*, but having an understory in which shade-tolerant conifers are well represented, are referred to as a successional stage of another habitat type.)

Vaccinium scoparium is well represented and usually dominates the undergrowth. *Calamagrostis rubescens* and *Arctostaphylos uva-ursi* are common associates at lower elevations. *Carex geyeri* and *Arnica cordifolia* are often conspicuous.

Soil.--Soils were derived from a broad variety of noncalcareous parent materials (appendix D-1). Surface soils were gravelly sandy loams to silts with very acidic to acidic reactions. Ground surfaces had an average of 5 percent rock but little bare soil exposed; duff depth averaged 4.7 cm.

Productivity/Management.--Timber productivity is low to moderate (appendix E-4). *Pinus contorta* is the only species that can be managed with assurance of success. Planting of other conifers should be done only on an experimental basis. Mule deer, elk, and occasionally moose use the areas lightly during the summer. Other management implications should be comparable to those for the *VASC* and *CARU* phases of the *ABLA/VASC* h.t.

Other studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) also recognized a *PICO/VASC* community type in central Idaho. However, Hoffman and Alexander (1976) designated a similar situation as a habitat type in Wyoming's Bighorn Mountains.

Pinus contorta/Calamagrostis rubescens community type
(*PICO/CARU* c.t.; lodgepole pine/pinegrass)

Distribution.--*PICO/CARU* c.t. is found near and east of the Continental Divide at 5,900 to 6,800 feet on cool exposures and benches, and between 6,600 and 7,500 feet on south-facing slopes.

Vegetation.--An overstory of nearly pure *Pinus contorta* is combined with a grassy undergrowth of *Calamagrostis rubescens* and associates, often including *Carex geyeri* as well as *Arnica cordifolia* or various other forbs. The three sample stands at lowest elevation (5,900 to 6,500 feet) had *Arctostaphylos uva-ursi* or *Spiraea betulifolia* associated with *Calamagrostis*, and were suggestive of the *PSME/CARU* h.t., *CARU* phase. Stands at higher elevations (6,700 to 7,500 feet) had little evidence of the potential climax. (Note that seral stands dominated by *Pinus contorta*, but having an understory in which shade-tolerant conifers are well represented, are referred to as a successional stage of another habitat type.)

Soil.--Soils were derived primarily from igneous parent materials (appendix D-1). Surface soils were acidic sandy loams to silts with average gravel content of 22 percent. Ground surfaces had little rock or bare soil exposed; duff depths averaged 2.6 cm.

Productivity/Management.--Timber productivity is low to moderate (appendix E-4). *Pinus contorta* is the only species that can be managed with assurance of success. Planting of other conifers should be conducted only on an experimental basis. Other management implications should be similar to those for the *PSME/CARU* h.t., *CARU* phase, or the *ABLA/CARU* h.t.

Other studies.--Robert Steele and others (1975 preliminary draft, USDA Forest Service, Intermountain Station) described a similar community type for central Idaho.

Cooper (1975, p. 35) described pure *Pinus contorta* communities in the Ashton-Henry's Lake area of Idaho, which he attributed to the *PSME/CARU* h.t. We would have left the question of climax on those sites open by assigning them to a *PICO/CARU* c.t.

Other Vegetation Types

The current classification does not define habitat types for all tree-covered areas in the State. North-central and northeastern Montana were not sampled. (Dr. Lee Eddleman of the University of Montana Forestry School is directing a cooperative study of forest habitat types in north-central Montana to be completed in 1978). Also not sampled were a few forest-grassland transitions, and some sites where succession toward climax is frequently disrupted by flooding. These areas do represent unique sites for plant community development and habitat type classifications could be developed for them in future studies. For sites where physical disturbance is part of the natural environment, classification can be based on the types of relatively stable plant communities that occur. The following communities are recognizable, based upon limited sampling (i.e., SCREE), observations, and cited reports:

FORESTED SCREE COMMUNITIES (SCREE)

Slopes covered with rock fragments are variously referred to in the literature as talus, scree, or rock debris. We have chosen to use the broad sense of the term "scree"--that is, any slope covered with loose rock fragments (Fairbridge 1968). The term is derived from the Old Norse word "skritha" which literally means "landslide, or the rock that slides away under the foot" (Gary and others 1972). Many of these sites are treeless, but those with finer rock often support an open forest cover. Ecologically, such stands can be considered as topo-edaphic climaxes, where the vegetation reaches a quasi-equilibrium with the constantly shifting substrate.

Forest vegetation on scree appears as a scattered, open stand of trees with a sparse undergrowth (fig. 47). Differences in size of rock fragments and rates of movement cause heterogeneity in vegetation development on a given site, and normal succession is constantly interrupted. Thus, the species composition is extremely variable, with some of the common indicator species of other habitat types appearing unpredictably. Vegetation data from 16 sample stands are listed in appendix C.

Our preliminary western Montana classification (1972) identified a *Pinus ponderosa* or *Pseudotsuga*/"SCREE" h.t. Further observations statewide showed *Pinus flexilis* and *Abies lasiocarpa* also to be associated with scree. It would be possible to reflect the general climate by identifying forested scree sites as habitat types within a series. However, because of the dominant topo-edaphic influence and the variability involved, we prefer to group all these sites under the general heading of Forested Scree (abbreviation "SCREE"). In the key, SCREE is separated out first at the series level to prevent users of the classification from trying to force a habitat type name on these sites.

SCREE is most often found on steep (greater than 30 degrees), dry, south- to west-facing slopes; it occurs over a broad elevational range--5,000 to 6,700 feet in our few samples taken east of the Continental Divide, and 3,100 to 7,150 feet west of the Divide. It is most abundant along the canyons of major streams. SCREE sometimes occurs on northerly aspects and occasionally as high as the upper subalpine forest zone.

SCREE is characterized by steep, unstable slopes, lack of soil development, stockability limitations, low site productivity, and regeneration difficulty. Uses of these sites should be restricted to those which occur naturally, such as use by wildlife. Hazards are too high and opportunities too low to attempt intensive management.

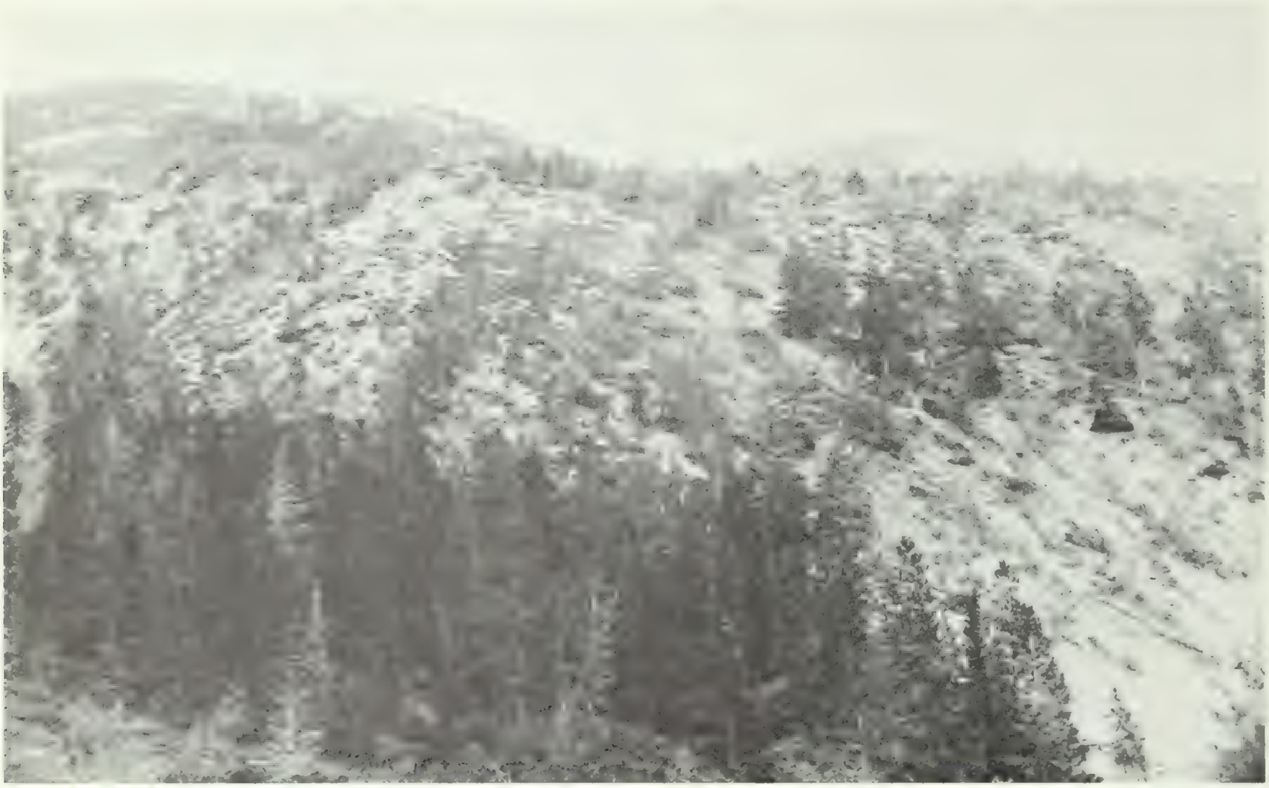


Figure 47.--Forested scree on a steep southwest exposure (5,800 feet elev.) southwest of Augusta in central Montana. Pinus flexilis *and* Pseudotsuga *are the principal tree species.* Arctostaphylos uva-ursi, Juniperus communis, Potentilla fruticosa, Prunus virginiana, Shepherdia canadensis, *and* Acer glabrum *are the common undergrowth plants.*

At high elevations, sites composed of large boulders are often treeless except for islands of stable vegetation attributable to specific habitat types--such as ABLA/*LUHI*, *ABLA/MEFE*, and *ABLA-PIAL/VASC*. Islands of a given habitat type thus may occur within a nonforested scree situation. The *LALY-ABLA* h.t.s occupy boulder-covered sites that are relatively stable.

BOTTOMLAND HARDWOOD FORESTS

These riparian forests are dominated by species of *Populus*, *Salix*, *Betula*, and *Alnus*, and by arborescent shrubs including *Cornus stolonifera*, *Sambucus coerulea*, *Sorbus scopulina*, *Acer glabrum*, *Crataegus* spp., and *Prunus* spp. They extend along rivers from the mountain forests far out into semiarid grasslands. Because of periodic destructive flooding, along with changes in stream channels and sedimentation, climax is rarely approached, even though conifers may be present with the hardwoods. Despite frequent disturbance, relatively stable plant communities develop and are identifiable. Analysis is complicated because these riparian forests are heavily grazed and otherwise disturbed by man's activities. Only a few undisturbed stands remain, usually on islands in the major rivers.

The following community types seem to exist, although stands were not sampled:

Populus trichocarpa-Pinus ponderosa Communities.--These are prevalent along the major alluvial valleys below about 4,000 feet elevation west of the Continental Divide, especially in west-central Montana. Foote (1965) sampled and described some of these stands.

Populus trichocarpa-Betula papyrifera Communities.--These occur at lower elevations (below about 3,500 feet) in relatively wet areas of northwestern Montana, such as the upper Flathead Valley. They often contain *Picea glauca X engelmannii,* and sometimes appear to be successional to *Picea* habitat types in the absence of severe flooding.

Populus trichocarpa Communities.--These are widespread at lower-to-middle elevations (below 6,000 feet), especially east of the Continental Divide in broad valleys isolated from the conifer forests or locally out of the range of *Pinus ponderosa.* The Jefferson, Gallatin, and Yellowstone River valleys support particularly extensive stands. In eastern Montana, comparable communities are dominated by the closely related *Populus deltoides.*

Salix-Betula occidentalis Communities.-- These occur in the high valleys near or east of the Continental Divide, mostly between 5,500 and 7,000 feet elevation. They are composed of small shrubby trees (10 to 20 feet tall) and are apparently associated with sites too cold for *Populus trichocarpa.* Examples include the Flint Creek and other headwater valleys of the Clark Fork River west of the Divide, and the Bighole, upper Madison, and other high valleys of southwestern Montana.

POPULUS TREMULOIDES STANDS

Populus tremuloides Climax Communities.--Pure stands of *Populus tremuloides* are found in the prairies immediately east of Glacier National Park. These self-perpetuating aspen stands are apparently the southward extension of the broad Canadian groveland found at the foot of the Rockies in Alberta and extending east across Alberta and Saskatchewan into southwestern Manitoba and adjacent Minnesota (Lynch 1955). Climax aspen stands apparently related to this groveland were noted in the current study as far south as Augusta (west of Great Falls). It is evident that the aspen groves have more soil moisture than the adjacent grassland (Lynch 1955). Conifers are at best marginally present in these situations and their reproduction may be prevented by abundant *Populus* and luxuriant undergrowth (Pfister 1972a). Small patches of climax aspen groveland may also occur to a limited extent farther south in Montana, near or east of the Continental Divide. Reed (1971), Wirsing (1973), and Hoffman and Alexander (1976) described three *Populus tremuloides* habitat types in Wyoming.

Populus tremuloides-Conifer Communities.--Most aspen groves in the Montana Rockies are quite small, and occur within or adjacent to conifer forest; they have apparently been perpetuated by periodic wildfires (Habeck 1970; Cooper 1975). With the current suppression of such fires, and especially where elk and other animals feed heavily on aspen, succession favoring *Abies lasiocarpa, Picea,* or *Pseudotsuga* is evident (Krebill 1972). Conifer regeneration is also apparent in many aspen stands, including those at the foot of the mountains on the eastern side of Glacier National Park (Habeck 1970). Presumably, stands with good representations of conifers should key to conifer habitat types. Cooper (1975) has also described *Populus tremuloides* stands in northwestern Wyoming where they are more extensive.

JUNIPERUS WOODLANDS

Stands of essentially pure *Juniperus scopulorum* cover small areas on rocky, dry sites in the higher valleys near the Continental Divide. We noted such stands in the vicinities of Drummond, Butte, Whitehall, and in the northern part of the Madison Range, but did not sample them. These coniferous woodlands, found well below the forest proper, are apparently a northern extension of the Great Basin "Pinyon/juniper" zone.

More commonly, *Juniperus scopulorum* is a minor associate with other conifers on low-elevation sites within the *Pinus flexilis, Pseudotsuga,* and *Pinus ponderosa* series.

SAVANNAS

Coniferous forest and mountain grassland are by far the two most extensive vegetational formations in the Montana Rockies. The boundary between them is usually well-defined. Mueggler and Handl (1974 preliminary draft, USDA Forest Service, Intermountain Station) have made a classification of grassland and shrubland habitat types in the Montana Rockies.

Our forest classification includes all stands having a potential of at least 25 percent forest canopy. Areas having 5 to 25 percent crown canopy coverage potential are termed savannas--grassland with scattered trees (Penfound 1967). Such areas are not extensive, but if encountered, they should be checked against both the grassland and forest classifications. (Neither study specifically sampled savannas.)

GREAT PLAINS FORESTS

Non-Rocky Mountain forests in eastern Montana were only marginally covered in this classification. Sampling was restricted to *Pinus ponderosa* forests in the Ashland and Roundup vicinities. Stands in the Missouri River Breaks northeast of Lewistown were not sampled, although Mackie (1970) described them. Isolated areas of mountain forests not sampled include the Bearpaw and Little Rocky Mountains, and the Sweetgrass Hills in north-central Montana, and the northern end of the Bighorn Range near the Wyoming line. Hoffman and Alexander (1976) should be useful in the latter area.

CHARACTERIZATON AND DISTRIBUTION OF HABITAT TYPES

Climate

Appendix D-2 shows key characteristics of the climate at stations representing various habitat types and phases. Most of the data are from U.S. Weather Service stations having 30-year normals or long-term records. The habitat type and phase shown for each of these stations is estimated to be the appropriate climatic climax. Often a reconnaissance plot was taken nearby.

Other climatic data representing specific forest habitat types in Montana may be available from Weather Service records or special studies made by various researchers. Even data taken at fire lookout sites may be useful if collected consistently and carefully for several summer seasons *and* if maximum and minimum thermometers or continuously recording hygrothermograph traces were used. Careful evaluation of the site is necessary to determine the appropriate climatic climax. For instance, climatic data from a site supporting an edaphic climax should be interpreted in relation to the nearest expression of a climatic climax, rather than the immediate edaphic climax.

Soils

Characteristics of the upper 10 cm of soil are summarized in appendix D-1 and as a paragraph in each habitat type description. Soil samples were first examined in the laboratory by an experienced soil scientist (Ronald McConnell, USDA Forest Service, retired) to determine structure, character of horizons, and textural class. Air-dry samples were then weighed, sieved (2 mm) to separate the gravel, and reweighed to determine percent gravel content. The soil separate was analyzed for wet color, dry color and pH, using the water-paste method with a 12-hour delay before reading with a glass electrode pH meter. The soil paste was then used to confirm the textural class designation. The gravel and larger coarse fragments were examined by geologists (Sigrid Asher-Moore and Cynthia Heliker, University of Montana, Missoula) to determine major parent materials.

Soil sampling and analyses were designed to obtain a simple characterization of surface soils for each habitat type, rather than detailed soil-vegetation relationships. Even our limited data make it evident that some habitat types are strongly controlled by edaphic or topo-edaphic factors and have a narrow range of soil characteristics; other habitat types occur on a broad range of soils.

One of the strongest influences of soil on vegetation in Montana is the presence of calcareous parent materials. The *PIPO/SYAL* h.t., *BERE* phase as well as the *PICEA/PHMA, PICEA/SEST, ABLA/CLPS,* and most of the *Pinus flexilis* h.t.s have a strong affinity for calcareous substrates. Dark-colored surface horizons were generally found in habitat types having either a grass-dominated undergrowth or calcareous substrates, although they were occasionally found in other habitat types as well.

Exposure of mineral soil and rock was greatest on the warm, dry habitat types of the *Pinus flexilis, Pinus ponderosa,* and *Pseudotsuga* series. Litter accumulation was lowest in these habitat types.

Several habitat types are associated with water tables close to the surface during part of the year (e.g., the *PICEA/EQAR, THPL/OPHO, ABLA/OPHO,* and *ABLA/CACA* h.t.s). Our samples indicate that these habitat types have less gravel, finer textures, lower pH, and deeper litter accumulation than adjacent upland sites; however, more complete soil descriptions would be necessary to adequately document these relationships.

A few research studies have documented soil characteristics by habitat type in the Northern Rockies. McMinn (1952) and Daubenmire (1968a) showed that soil moisture depletion rates differ substantially among habitat types, and this helped explain the differences in vegetation. Work is currently being conducted by the Soil Conservation Service (Harold Hunter, Bozeman) and the Bitterroot National Forest (B. John Losensky, Hamilton) to measure relationships between habitat types and soil temperatures.

It is often theorized that vegetation or habitat types can be predicted from soil characteristics. But R. and J. Daubenmire (1968) have emphasized that the correlation between habitat types and soil types (classified on the basis of standard soil profile characteristics) is too weak to allow prediction of habitat types from soil types, or vice versa. We subscribe to this viewpoint as a general rule for several reasons. First, the development of a soil profile reflects a long-term integration of soil forming factors, whereas vegetation development is much more sensitive to current climatic conditions. Second, soil classification systems are not designed to primarily reflect influences on vegetational development; therefore, predictive capabilities should not necessarily be expected. Third, vegetational development depends on many factors, of which soil characteristics is only one. According to the principle of factor interaction, species are able to grow on a wide range of substrates when other factors provide compensatory effects.

In summary, land managers should be cautious about attempting to "shortcut" inventories of either vegetative potentials or soils through the process of "assumed correlations." Some useful correlations undoubtedly exist; but they must be developed objectively, tested adequately, and extrapolated with caution.

Vegetation

OCCURRENCE OF SPECIES

Appendix B is an interpretation of tree species occurrence in habitat types and phases. This provides the basic information for selecting and managing tree species based on their environmental adaptation and successional role in specific habitats.

Appendix C-1 provides constancy and average coverage data for 93 "important" species (those with major occurrence or indicator significance) for each of the habitat types and phases. This table can be used (1) for gaining more insight into the structure of the classification than the key or the written type descriptions provide; (2) as a summary of composition in the relatively mature (70 years and older) sample stands; and (3) for evaluating the ecological amplitude and abundance of any species for the later successional stages of the entire classification.

Appendix C-2 provides a detailed presence list by habitat type. This includes all species that occurred in five or more of the approximately 1,500 sample stands.

How to use species occurrence data.--The following examples show how to use appendixes B, C-1, and C-2 to determine the distribution and relative importance of plants by habitat type. Keep in mind, however, that the potential application of these appendixes is much broader than shown in these introductory examples.

Question 1.--Is *Artemisia tridentata* found in the *Pseudotsuga menziesii/Festuca idahoensis* h.t., and if so, how abundant is it?

Data (from appendix C-1): *PSME/FEID* h.t.

19 stands

constancy ⟶ 6 (5) ⟵ average percent coverage

Answer: Constancy is about 60 percent (see code at bottom of appendix C-1). This means that 11 or 12 of the 19 sample stands had some *Artemisia tridentata*. The coverage value shows that *Artemisia* had an average canopy coverage of 5 percent in the stands where it occurred.

Question 2.--Is *Artemisia tridentata* a major undergrowth species in Montana forest stands?

Data: Appendix C-1 shows that *Artemisia tridentata* was found in 11 of the 100 habitat types and phases listed. However, only in 3 types and phases did it have a constancy of 50 percent or more:

PIFL/AGSP h.t.	*PIFL/FEID* h.t.	*PSME/FEID* h.t.
6 stands	7 stands	19 stands
5 (1)	6 (1)	6 (5)

Average canopy coverage by *Artemisia* is only 1 percent (even in those stands where it does occur) except in the *Pseudotsuga/Festuca idahoensis* h.t.

Answer: Evidently *Artemisia tridentata* is not a major undergrowth species in mature forest stands, with the limited exception of the *Pseudotsuga/Festuca idahoensis* h.t.

Question 3.--If you were given seedlings of *Acer glabrum* to plant for big game habitat purposes, which of the following habitat types would you choose for planting them in?

PIPO/FEID h.t., *FEID* phase
PSME/FESC h.t.
ABLA/VACA h.t.
PSME/PHMA h.t., *PHMA* phase
PSME/CAGE h.t.
THPL/CLUN h.t., *CLUN* phase

Data: This species is not shown in appendix C-1 (Constancy and Average Coverage); therefore, appendix C-2 (Presence List) will have to serve as the source of data. According to appendix C-2, *Acer glabrum* was absent in three of the habitat types--*PIPO/FEID, PSME/FESC,* and *ABLA/VACA*--and was present in only 1 out of the 10 stands in *PSME/CAGE* h.t. By contrast, it occurred in 18 of 45 stands in the *PSME/PHMA* h.t., *PHMA* phase, and in 10 of 15 stands in *THPL/CLUN* h.t., *CLUN* phase.

Answer: Thus, only *PSME/PHMA* and *THPL/CLUN* are logical choices.

Question 4.--Which tree species occur in the *PSME/CARU* h.t., *CARU* phase? What are their successional roles and how abundant are they?

Answer (provided by data from appendixes B and C-1):

PSME/CARU h.t., *CARU* phase

Species	*(Appendix B)* *Role*	*(Appendix C-1)* *Constancy (average coverage percent)*
Pinus ponderosa	a = accidental	2 (1)
Pseudotsuga menziesii	C = major climax	10 (60)
Pinus contorta	(S) = major seral in part of the phase	6 (20)
Larix occidentalis	(s) = minor seral in part of the phase	1 (11)
Abies lasiocarpa	a = accidental	1 (1)
Pinus albicaulis	a = accidental	1 (3)

TIMBER PRODUCTIVITY

Timber productivity is one of the key management implications for which data were collected during this study. Site trees were selected to determine the potential height growth of relatively free-growing trees. One site tree of each species was selected for each stand wherever possible. Site trees showing marked diameter-growth suppression for a period of 10 or more years were rejected during analysis of the increment cores. Old-growth and stagnated trees were not used for productivity estimation. Even though only a single site tree per species per stand was used, the data are reasonably consistent. Comparisons appear to be valid, and the sample size (794 stands) permits comparison of productivity among habitat types as well as within each habitat type.

Determination of site index from height-age data requires specific procedures for each tree species. The number of years to reach breast height (4.5 feet) must be measured or estimated for species having height-total age site curves. If a site curve is not available, a curve from another species must be selected as a substitute. Criteria used to determine total age, as well as sources of site index curves and yield capability data for this analysis, are summarized in table 7.

Table 7.--*Criteria and sources for determining site index and for estimating yield capability*

Species	Estimated years to obtain breast height	Source of site curve[1]	Yield capability (all trees - fig. 8)
PIPO	10	Lynch 1958	Brickell 1970
PSME	10	----------------Used PIPO curves------------------	
PICO	10 5-West side	Alexander 1966	Used LAOC curve[2]
LAOC	5	Schmidt and others 1976	Schmidt and others 1976[2]
PICEA	(3)	Alexander 1967	Alexander[4]
ABGR	(3)	Stage 1959	
ABLA	(3)	----------------Used PICEA curves------------------	
PIMO	5	Haig 1932	Brickell 1970
TSHE	10	Deitschman and Green 1965[5]	Used PIMO curve
THPL	(3)	----------------Used PICEA curves------------------	
TSME	(3)	----------------Used PICEA curves------------------	
LALY	(3)	----------------Used PICEA curves------------------	
PIAL	(3)	----------------Used PICEA curves------------------	
PIFL	(3)	----------------Used PICEA curves------------------	

[1] All site curves with a 100-year index age were converted to a 50-year index age.

[2] Brickell's (1970) curves for PICO and LAOC (trees larger than 5.0 inches) were nearly identical. A new curve (based on all trees) was developed for LAOC from yield data in Schmidt and others (1976). The LAOC curve for all trees appears to be as accurate as any available for estimating PICO yield capability for all trees.

[3] Curves based on age at breast height were used.

[4] Data used in a recent yield study (Alexander and others 1975) were provided by Alexander. Site index and mean annual increment from 21 fully-stocked natural stands were used to develop the curve shown in figure 8. (Yield capability = -26.0 + 1.84 Site Index (50); $R^2 = 0.66$).

[5] TSHE height and age were used to estimate PIMO site index.

We used *Pinus ponderosa* curves for determining *Pseudotsuga* site index rather than Brickell's (1968) *Pseudotsuga* curves, because the curve shapes for *Pinus ponderosa* are more realistic for our data (giving closer estimates for different aged site trees in the same stand). Furthermore, since *Pinus ponderosa* yield tables are currently used to estimate *Pseudotsuga* yields in the Northern Rocky Mountains, it is more logical to use *Pinus ponderosa* site index for estimating *Pseudotsuga* yields.

We used Alexander's (1967) *Picea engelmannii* curves for *Picea* rather than Brickell's (1966) because: (1) Alexander's are based on breast-height age (data available) rather than total age (estimate required); (2) the curve shapes are more realistic for our data (giving closer estimates for different aged site trees in the same stand); and (3) yield data related to the curves are available (Alexander and others 1975). We also used Alexander's (1967) *Picea engelmannii* curves for several other species that lack site-index curves; because they do not require breast-height age estimates. Thus a possible source of estimation error is eliminated.

The site-index data (base age 50 years) have been summarized by species within habitat types (appendix E-1). Because of regional differences in habitat-type occurrence as well as apparent regional differences in productivity for some habitat types, all timber productivity data were summarized separately for west-side and east-side forests. The mean site index was calculated whenever three or more values were available. With five or more values, a 95-percent confidence interval for estimation of the true population mean was calculated. (The confidence interval narrows with both decreased variability and increased sample size.) The same procedure was used for summarizing basal areas of sample stands.

The maximum heights observed in old-growth stands (>200 years) are presented in appendix E-2. These data can be used for simple comparisons and for identifying sites where height is severely limited.

Although site productivity can be compared by using site index alone, a more useful assessment can be made by using the estimated net yield capability of the site (cubic-foot production). Until managed-stand yield tables are completed, the best approach is to use natural-stand yield tables for assessing yield capability. As stated by Brickell (1970), "Yield capability, as used by Forest Survey, is defined as mean annual increment of growing stock attainable in fully stocked natural stands at the age of culmination of mean annual increment." (In other words, yield capability = maximum mean annual increment attainable in fully stocked natural stands. For additional explanation see Glossary, appendix G.)

The curves used to estimate yield capability from site index are presented in figure 48.

Yield capability values are based on cubic feet of all trees (>0.5 inch d.b.h.). The *Larix occidentalis* curve was derived from Schmidt and others (1976). (Brickell's 1970 curve for this species was only for trees greater than 5.0 inches in diameter.) The *Larix* curve was also used for *Pinus contorta* because Brickell's (1970) curves (trees >5.0 inches) are almost identical for the two species, and because natural stand yield data have not been published for *Pinus contorta*.

The *Picea* curve was derived from original data used in developing managed-stand yield tables (Alexander and others 1975). We calculated mean annual increment for all trees for 21 of Alexander's fully stocked natural stands near the age of culmination of mean annual increment (ages from 97 to 165 years). A linear regression of yield capability on Alexander's (1967) site index was conducted, converted to site index at base-age 50, and plotted in figure 48. [Yield Capability = -26.0 + (1.84 X 50-year site index.) $R^2 = 0.66$]. The other curves were developed by Brickell (1970) from natural-stand yield tables.

The spread in these curves indicates that natural-stand yield capability for a given site index is considerably higher in *Abies grandis*- and *Pinus monticola*-dominated stands than for other species. This illustrates the importance of using species-specific curves for estimating productivity.

Our best current estimates of yield capability (in cubic feet/acre/year) for each habitat type are shown in appendix E-3 (west-side) and E-4 (east-side). Procedures used to develop these estimates were:

1. Yield capability was estimated for each site tree from appropriate species curves according to the criteria in table 7. These values were plotted by species within habitat types and phases for a visual display of distribution.

2. Mean yield capability for all site trees in each habitat type was calculated and cutoff points were established to approximate 90 percent of the range of our data.

3. For habitat types where stockability appears to limit productivity, a stockability factor was developed. Basal area data for plots in these types were compared with Meyer's (1938) basal area data for fully stocked "normal" stands, following the approach of MacLean and Bolsinger (1973). From these calculations and additional observations, an average mean stockability factor was determined for several habitat types. This factor was multiplied by yield capability for a given site index to determine the adjusted yield capability. A factor of ±0.10 was used to expand the estimated range of productivity.

These current best estimates (appendixes E-3 and E-4) portray both relative productivity of habitat types and the range of productivity within a habitat type. From these, it is possible to assign a ranking or qualitative rating of potential timber productivity of natural stands for use in planning.

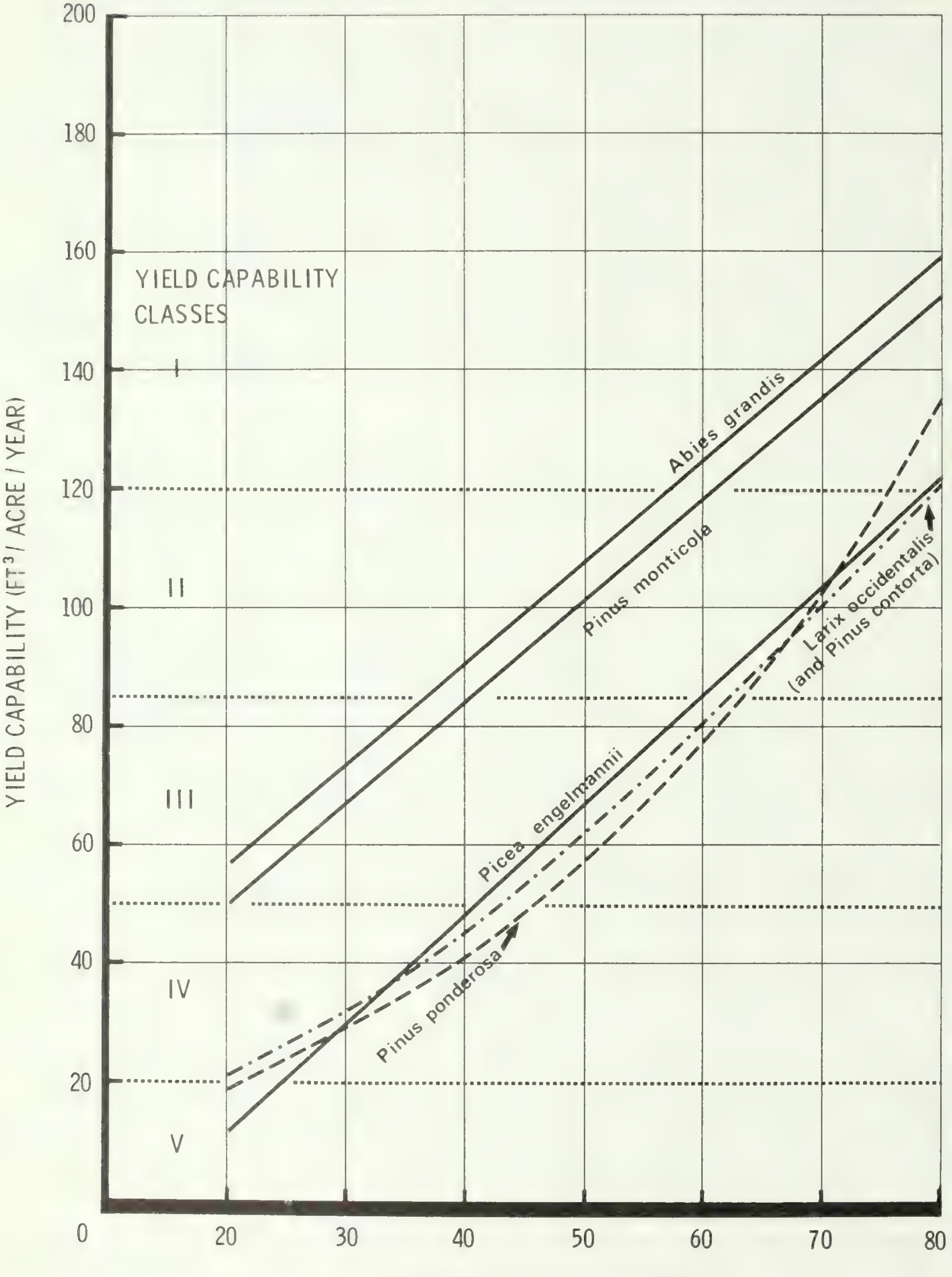


Figure 48.--Yield capability of fully stocked natural stands in relation to site index.

As Daubenmire (1976) emphasized, natural vegetation serves as a convenient indicator of productivity over large areas of land. However, productivity within habitat types (appendix E) often shows substantial variability. The following points help explain this variability, and give suggestions for reducing it.

1. Site-index curves were used to obtain productivity data from yield tables. Different height-growth patterns undoubtedly occur on different sites, but data to account for this variation are not available.

2. Yield tables and site curves have not been developed for all species, making extrapolation necessary.

3. Yields of mixed species stands can be estimated by several individual species' yield tables. We found that a range of 30 to 40 cubic feet/acre/year in yield capability was common in individual stands, depending upon the species used for estimation.

4. Some variability in productivity within a habitat type is logical in a natural classification system. The habitat type classification is based on abilities of species to reproduce and mature under competition, not on their rates of growth. The correlation between this and productivity is imperfect. (For instance, in some stands tree roots draw on underground water tables and achieve excellent growth rates, while surface drought limits development of tree seedlings and undergrowth.)

5. Where a more accurate estimate of productivity is needed for local areas, we recommend taking additional site-index samples.

6. It has been suggested that productivity estimates for habitat types could be improved by incorporating classifications of soils, topography, or climate. We have demonstrated a major regional difference in productivity by separating west-side and east-side data (appendix E). Differences in productivity within a habitat type due to topography or soils are also apparent in some local areas. However, because of the limitations of existing site index curves and yield tables, further refinement of productivity data for large areas should be based on more precise methods of measuring productivity.

7. Natural-stand yield capability by habitat type could be estimated more precisely by direct measurements of volume growth, rather than by using site index to enter a yield table based on averages. This would require analysis of existing timber inventory plots representing maximum growth potential or new field measurements.

8. Recent stand growth models (Stage 1973, 1975) utilize growth coefficients based on habitat types. These add a new dimension to yield prediction, provide the basis for developing managed-stand yield tables, and should improve our knowledge of productivity within and between habitat types.

Geographic Distributions of Habitat Types

As discussed in their individual descriptions, most habitat types are restricted to certain areas within the Montana Rockies. Many of them--including the entire *Abies grandis*, *Thuja*, and *Tsuga* series--are confined to northwestern and west-central parts of the State. Others, including the entire *Pinus flexilis* series, are found only near or east of the Continental Divide. Only a few--e.g., *PSME/CARU*, *PSME/SYAL*, *PIAL-ABLA*--are relatively common throughout the Montana Rockies.

The geographical distribution of each habitat type is reflected in appendix A, which shows the number of sample plots in each habitat type and phase taken in each of 12 portions of the State. Absence of sample plots in a given area does not necessarily indicate that the habitat type is not present, but it does suggest that it is at most of minor occurrence.

Figures 49 through 56 are schematic diagrams of the pattern of forest habitat types and phases found in seven areas of Montana. *These diagrams are not literally accurate,* but they do attempt to portray the arrangement of all major habitat types likely to be found in a given vicinity. On a specific mountainside or in a small drainage, as few as half of the types depicted for that general vicinity may be present. These diagrams also illustrate the criteria used in defining the classification units.

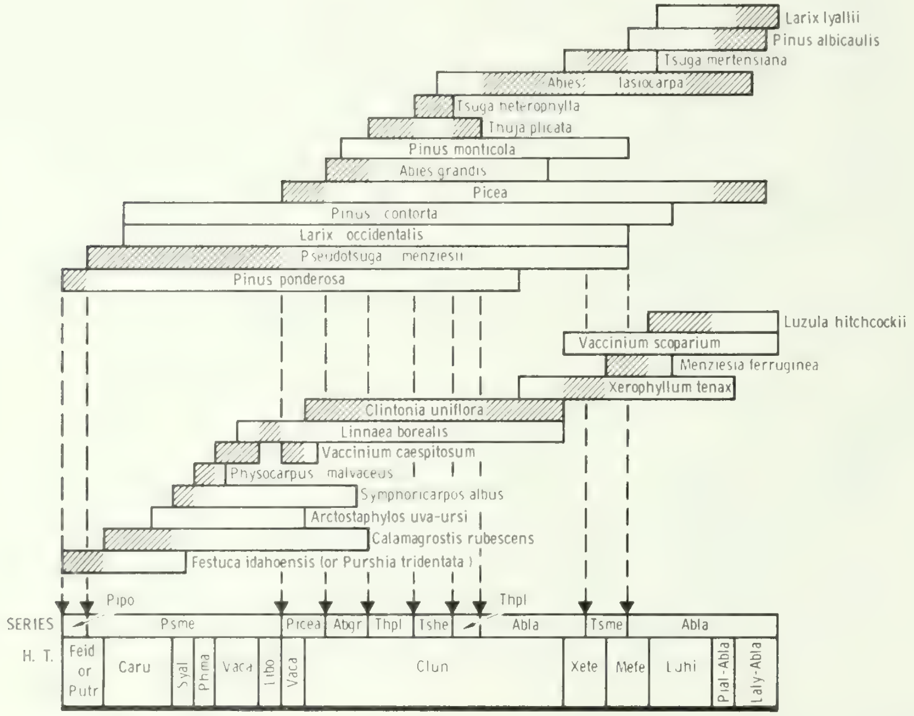


Figure 49.--Schematic distribution of tree and key undergrowth species usually encountered with increasing elevation (from left to right) in mature forest stands near Libby. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.

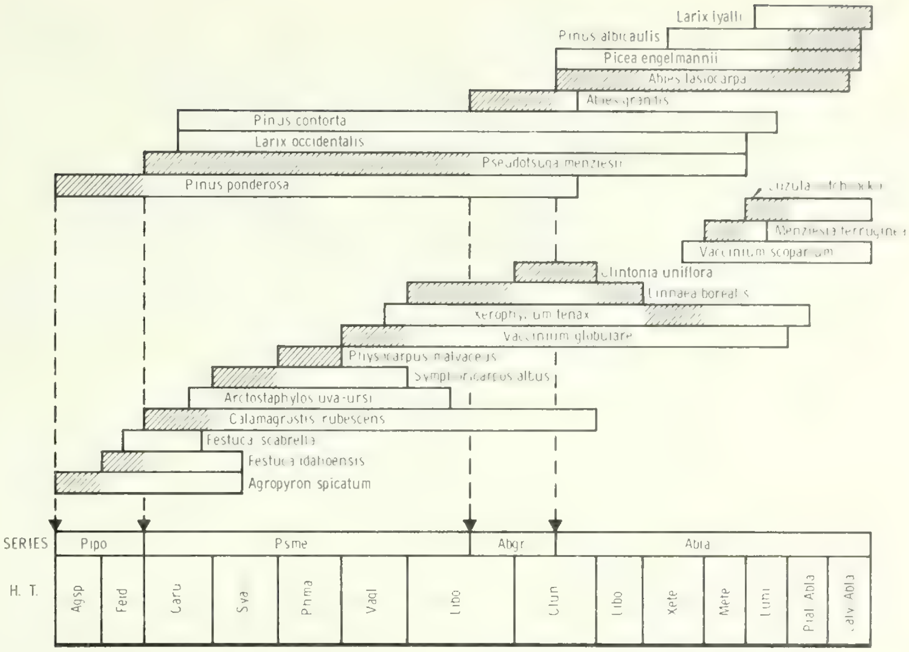


Figure 50.--Schematic distribution of tree and key undergrowth species usually encountered with increasing elevation (from left to right) in mature forest stands near Missoula. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.

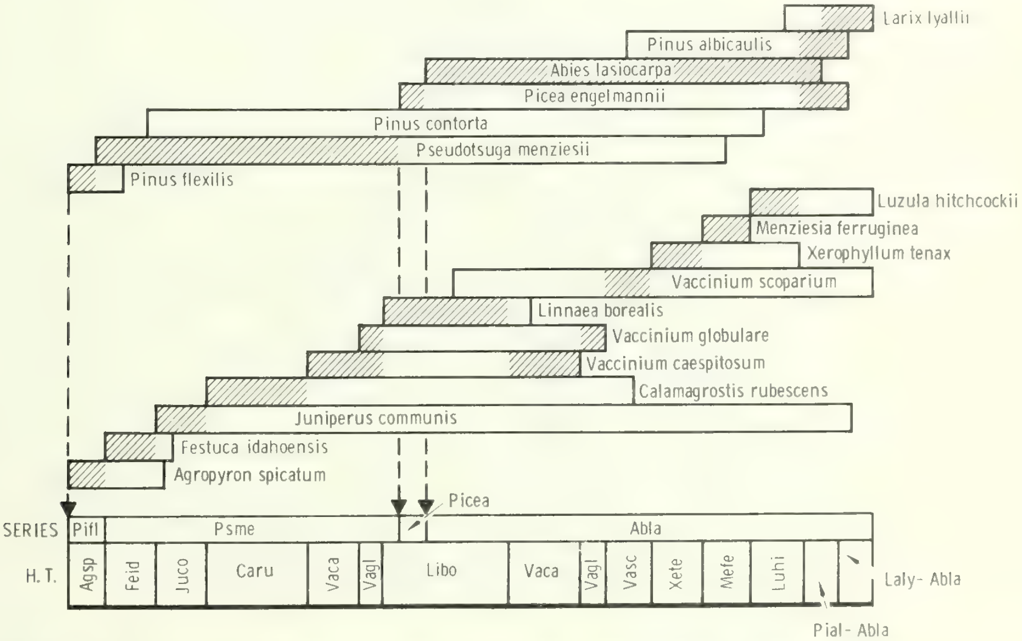
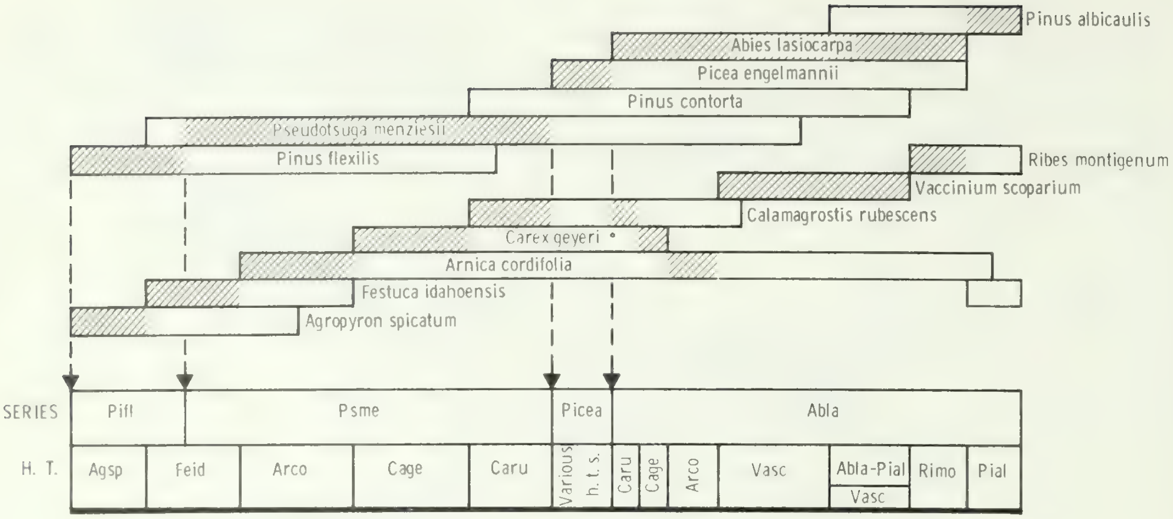


Figure 51.--Schematic distribution of tree and key undergrowth species usually encountered with increasing elevation (from left to right) in mature forest stands in the vicinity of Butte and Philipsburg. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.



* the upper limits of Cage are not well defined.

Figure 52.--Schematic distribution of tree and key undergrowth species usually encountered with increasing elevation (from left to right) in mature forest stands in the vicinity of Dillon and Lima. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.

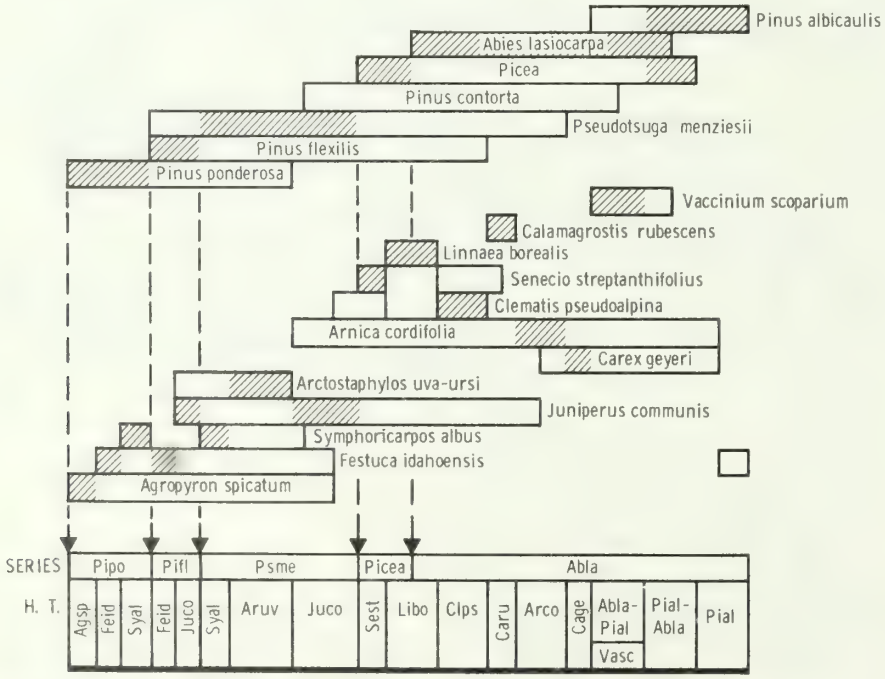


Figure 53.--Schematic distribution of tree and key undergrowth species usually encountered with increasing elevation (from left to right) in mature forest stands on limestone *substrates in the Little Belt Mountains. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.*

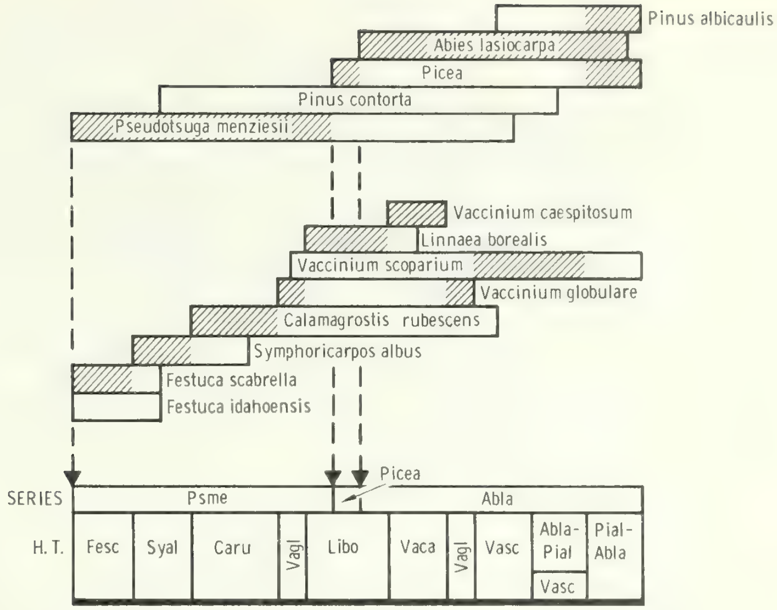


Figure 54.--Schematic distribution of tree and key undergrowth species usually encountered with increasing elevation (from left to right) in mature forest stands on nonlimestone substrates in the Little Belt Mountains. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.

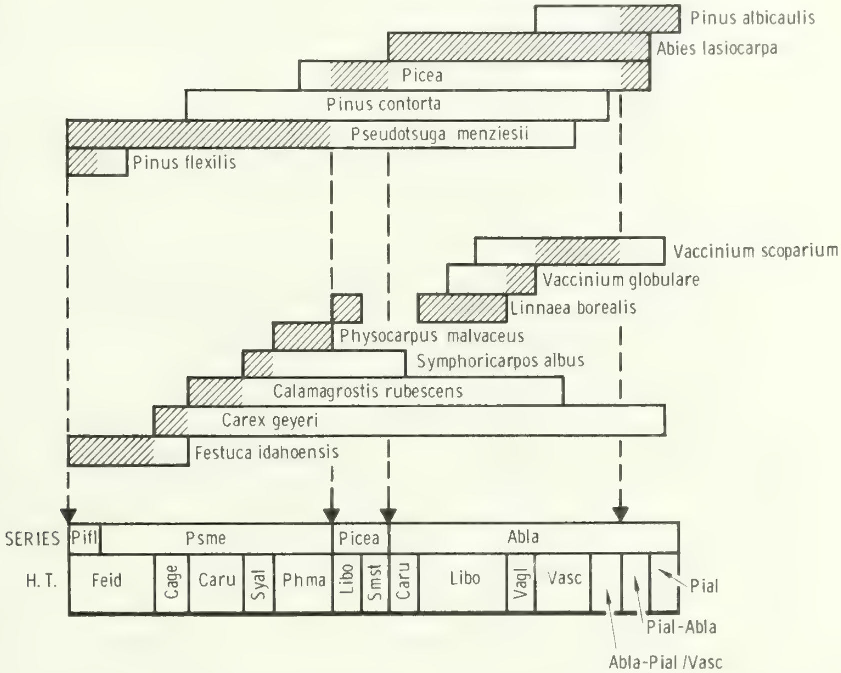


Figure 55.--Schematic distribution of tree and key undergrowth species usually encountered with increasing elevation (from left to right) in mature forest stands in the Gallatin and Absaroka Ranges. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.

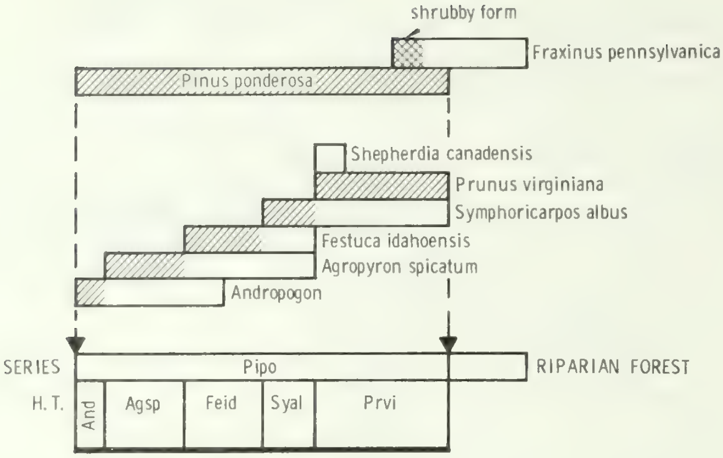


Figure 56.--Schematic distribution of tree and key undergrowth species usually encountered with increasing soil moisture (from left to right) in mature forest stands near Ashland. The horizontal bars designate lower and upper limits of the species. That portion of the tree species' range where it is considered climax is indicated by shading. That portion of the undergrowth species' range where it is used to define a habitat type is indicated by shading.

Relationship to Other Habitat Type Classifications

The Montana classification was developed through successive steps of data analysis and field testing; two preliminary classifications (1972, 1973) and a review draft (1974) were made available for field testing. The relationships of our classification to R. and J. Daubenmire's (1968) classification (which had been extrapolated to Montana prior to this study) as well as development from the preliminary classifications are illustrate in figure 57. This figure provides a means of translating fieldwork done with a preliminary classification to the current habitat type designations, and of comparing information from habitat types in northern Idaho.

The Montana forest classification is also closely related to concurrent studies in central Idaho and the Nezperce National Forest (Robert Steele and others 1975, 1976, preliminary drafts, USDA Forest Service, Intermountain Station) as well as northwestern Wyoming and adjacent portions of Idaho (Cooper 1975). As discussed in the habitat type writeups, many of the individual types are related to types or communities described in a number of other studies from areas outside of the Northern Rockies (McLean 1970; Ogilvie 1963; Reed 1969; Pfister 1972a; Thilenius 1972; Hall 1973; Hoffman and Alexander 1976). Forest habitat type classifications now being conducted in other areas will be compared with ours at a later date.

Figure 57.--The relationship of the final Montana classification to preliminary reports and to R. and J. Daubenmire's (1968) stand data.

R. & J. DAUBENMIRE (1968)	WESTERN MONTANA 1972	CENTRAL & EASTERN MONTANA – 1973	MONTANA H. T. S. 1977
▨	SCREE	SCREE	SCREE
	▨		
		PIFL/AGSP	PIFL/AGSP
		(PIFL-PSME/FEID)	PIFL/FEID
		PIFL/JUCO	PIFL/JUCO
PIPO/STIPA		▨	▨
▨			PIPO/AND
PIPO/AGSP	PIPO/AGSP	PIPO/AGSP	PIPO/AGSP
▨	▨		
PIPO/FEID	PIPO/FEID	PIPO/FEID	PIPO/FEID FEID Phase FESC
▨			
PIPO/PUTR	PIPO/PUTR	▨	PIPO/PUTR AGSP FEID
		PIPO/PUTR	
PIPO/SYAL	PIPO/SYAL	▨	▨
		PIPO/SYAL	PIPO/SYAL SYAL BERE
▨	▨	▨	
		PIPO/PRVI	PIPO/PRVI PRVI SHCA
PIPO/PHMA		▨	▨
▨	PIPO/CARU		
	▨		PSME/SYOR
	PSME/AGSP	PSME/AGSP	PSME/AGSP
		PSME/FEID	PSME/FEID
			PSME/FESC
	PSME/SYAL	▨	PSME/SYAL AGSP SYAL CARU
PSME/SYAL		PSME/SYAL	
		PSME/SPBE	PSME/SPBE
▨	PSME/PHMA	▨	PSME/PHMA CARU PHMA
PSME/PHMA		PSME/PHMA	
▨	PSME/LIBO	PSME/LIBO	PSME/LIBO SYAL CARU VAGL
	PSME/XETE	▨	
		PSME/VAGL	
			PSME/VAGL VAGL ARUV XETE
		▨	
PSME/CARU			
	PSME/CARU	PSME/VASC	PSME/CARU CARU ARUV PIPO AGSP
		PSME/CARU	
		▨	
▨			
		PSME/CAGE	PSME/CAGE
	PSME/VACA	▨	PSME/VACA
	▨	PSME/JUCO	PSME/ARUV
			PSME/JUCO
		PSME/ARCO	PSME/ARCO
	PICEA/LIBO	PICEA/LIBO	PICEA/LIBO
		▨	PICEA/CLUN CLUN VACA
			PICEA/VACA
	▨	PICEA/PHMA	PICEA/PHMA
		PICEA/EQAR	PICEA/EQAR
		PICEA/GATR	PICEA/GATR
		PICEA/GERI	PICEA/SMST
		▨	PICEA/SEST PSME PICEA

R. & J. DAUBENMIRE (1968)	WESTERN MONTANA 1972	CENTRAL & EASTERN MONTANA–1973	MONTANA H.T.S. 1977
▨	ABGR/XETE	▨	ABGR/XETE
ABGR/Pachistima	ABGR/CLUN		ABGR/LIBO XETE Phase LIBO
▨			ABGR/CLUN CLUN XETE ARNU
THPL/Pachistima ▨	THPL/CLUN		THPL/CLUN CLUN ARNU MEFE
THPL/Athyrium	▨		▨
THPL/OPHO	TSHE/OPHO		THPL/OPHO
TSHE/Pachistima	TSHE/CLUN		TSHE/CLUN CLUN ARNU
▨	ABLA/OPHO		ABLA/OPHO
ABLA/Pachistima	ABLA/CLUN	ABLA/CLUN ▨	ABLA/CLUN VACA XETE CLUN MEFE ARNU
		ABLA/GATR	ABLA/GATR
▨	▨	ABLA/CACA ABLA/VACA	ABLA/CACA GATR CACA VACA
			ABLA/VACA
ABLA/MEFE and TSME/MEFE	ABLA/MEFE, TSME/MEFE	ABLA/MEFE	ABLA/MEFE and TSME/MEFE
ABLA/XETE and TSME/XETE	ABLA/LUHI	▨ ABLA/LUHI	TSME/LUHI, ABLA/LUHI MEFE VASC
▨	ABLA/XETE TSME/XETE	ABLA/XETE	ABLA/XETE, TSME/XETE VAGL
	▨	ABLA/LIBO	ABLA/LIBO XETE LIBO VASC
	ABLA/VASC	ABLA/VASC	ABLA/XETE VASC
ABLA/VASC	▨		ABLA/VASC VASC THOC CARU
▨		ABLA/VAGL	ABLA/VAGL
		ABLA/ALSI communities	ABLA/ALSI
		ABLA/CARU	ABLA/CARU
		ABLA/CAGE	ABLA/CAGE PSME CAGE
		unclassified communities	ABLA/ARCO
		ABLA/CLPS	ABLA/ CLPS
		ABLA/RIMO	ABLA/RIMO
		ABLA-PIAL/VASC	ABLA-PIAL/VASC
PIAL-ABLA	PIAL– ABLA	PIAL-ABLA	PIAL-ABLA H. T. S.
	LALY– ABLA	LALY-ABLA	LALY-ABLA H. T. S.
▨	▨	PIAL	PIAL H. T. S.
		PICO/PUTR	PICO/PUTR

USE OF THE CLASSIFICATION

Validation

Our objective has been similar to that of R. and J. Daubenmire (1968)--that is, to develop an ecological classification of forest land in which not only vegetation but also climate, geography, and disturbance factors are taken into account. Vegetation characters are convenient to use for this purpose, and the natural vegetation that develops over a long period of time without disturbance is felt to reflect the overall environment. It acts like a complex environmental monitoring system. R. and J. Daubenmire (1968) stated the goal of such ecological classifications as follows: "That system . . . closest to a natural one that allows the most predictions about a unit from a mere knowledge of its position in the system."

The current Montana classification culminates 4 years of intensive research. Although its preliminary drafts have had the benefit of 3 years of testing by land managers, further refinement is always possible.

Use of Habitat Types

Layser (1974) and Pfister (1976) have outlined potential values of habitat types in resource management. Perhaps the most important overall use is as a land stratification system--designating land areas with similar environments or biotic potential--thereby providing a tool for cataloging and communicating research results, administrative study results, accumulated field observations, and intuitive evaluations. The habitat type classification is presented as a foundation for basing predictions of response to land and vegetation management activities. However, habitat types are *not* a panacea for decisionmaking or research interpretations. Rather, habitat types will complement information on current (seral) vegetation, soils, outdoor recreation, socioeconomic conditions, hydrology, and wildlife. For instance, although habitat types do not include a description of young seral communities which would be useful for wildlife, range, silviculture, etc., this classification of sites and mature forest communities does provide the foundation upon which successional stages can be studied and defined. Habitat types will also aid more intensive land management and land use planning.

Some of the current and potential uses of habitat types include:

1. Timber management--developing seed source and seed transfer rules, serving as a stratification for tree improvement programs, selecting species for planting (Pfister 1972b), comparing natural regeneration (Shearer 1976), evaluating cutting and regeneration methods, and assessing relative timber productivity.

2. Range and wildlife management--assessing relative forage production, comparing potential values for domestic grazing, and evaluating summer and winter use by big game (Lyon 1975; Marcum 1975).

3. Watershed management--estimating relative precipitation, evapotranspiration, and moisture-holding characteristics.

4. Recreation--assessing suitability for various types of recreational use, evaluating impacts of use on plant communities and sites (Helgath 1975; Dale 1973), and predicting recovery rates following disturbance.

5. Forest protection--categorizing fuel buildup, implementing fuel management, and evaluating the natural role of fire including frequency and intensity of burns (Aldrich 1973; Arno 1976); and assessing susceptibility to various insects and diseases.

6. Natural area preservation--helping to insure that the environmental spectrum is adequately represented in research natural areas (Schmidt and Dufour 1975).

Some management implications are discussed in the descriptions of the habitat types in this report. Additional implications can be developed from the appendix data. Valuable information regarding the response of each habitat type to specific treatments can be obtained by carefully documenting and analyzing field observations. Also, field research studies in many functions can use the habitat types as a stratification for designing studies. Study results can then be reported in a form suitable for application on appropriate habitat types.

Mapping

Habitat type maps have become an important management tool in the Northern Region of the USDA Forest Service (Deitschman 1973; Stage and Alley 1973; Daubenmire 1973). They provide a permanent record of habitat type distribution on the landscape and a basis for acreage estimates for land-use planning.

Maps may be made at various scales and degrees of accuracy, depending upon objectives. For research studies, project planning, etc., maps should be accurate and detailed; each phase of a habitat type should be delineated, especially for research studies. The map scale should range from 4 to 8 inches per mile. At a broader level of planning (multiple use planning unit, National Forests, etc.) map accuracy and detail may decrease and mapping efforts may be extensive. Habitat types are often the finest subdivisions shown, and map scale can range from 1 to 2 inches per mile.

Still broader levels of mapping may be required for regional needs (selection of powerline corridors, State or regional planning); these may employ scales of 1/4 to 1/2 inch per mile, and may depict only habitat type groups or series. These should be synthesized from large-scale habitat type maps whenever the latter are available.

Selecting a mapping approach and appropriate scale to produce an acceptable map must be based on the following: (1) anticipated use of the map, (2) accuracy level required, (3) availability of adequately trained personnel, and (4) amount of time and financial support available to achieve the specified accuracy level.

At scales of 4 to 8 inches per mile, the habitat types or phases are useful as the mapping units, accepting inclusions (up to 15 percent) of other types too small to map separately. In complex topography and at smaller map scales, special mapping units must be developed, which may be called complexes or mosaics. Such mapping-unit complexes must be defined for each area being mapped, rather than on a preconceived grouping. The amount and relative positions of habitat types and phases within a complex must be specified because the management interpretations of a mapping unit are tied to the taxonomic units--series, habitat type, and phase.

Regardless of the mapping scale used, the field reconnaissance should identify stands to the phase level. The amount and location of field reconnaissance should also be specified on the map or in a report for users of the map. Finally, the map accuracy should be estimated and checked to maintain quality control in application of the habitat type classification.

Grouping

Since this classification system for potential vegetation is hierarchical, it can be used at various levels of differentiation for various purposes. Field data (vegetational inventories) for determining habitat type and phase should be collected accurately and recorded for future reference--for instance, using a checklist (appendix F). This approach is only slightly more time-consuming than taking cruder field data. It enhances the value of the data and the comprehension of the investigator; moreover, it helps provide a basis of professional credibility for the work. Above all, it provides flexibility in the ultimate use of the data. In contrast, if habitat-type groups are assigned in the field, reevaluation or more detailed analysis is not possible. Without field data, the probability of an unsatisfactory product is high.

Relatively few habitat types and phases occur in a given forested area. Moreover, some of these will be so minor in extent that once their presence is documented they need not enter into most broad-scale forest management considerations. This leaves a relatively small number of habitat types to be identified (and mapped) in a given area. After the distributional patterns of all the habitat types have been identified, the types can be grouped in logical categories to facilitate resource planning and public presentations.

Where implications for management are similar, it may be desirable to consider an entire series (e.g., *Pinus flexilis* series, or *Abies grandis* series) as one group. Conversely, where management considerations contrast strongly even at the phase level (e.g., the phases of *PSME/CARU* h.t.), it may be desirable to split a habitat type in the grouping process.

Below is one example of a grouping made on the basis of overall ecological similarities including geographical distributions:

Pinus flexilis series
PIPO/AND; PIPO/AGSP; PIPO/FEID; PIPO/PUTR h.t.s
PIPO/SYAL; PIPO/PRVI h.t.s
PSME/AGSP; PSME/FEID; PSME/FESC; PSME/SYOR h.t.s
PSME/VACA; PSME/CARU h.t., *ARUV* phase
PSME/PHMA; PSME/SYAL h.t., *SYAL* and *CARU* phases
PSME/VAGL; PSME/LIBO h.t.s
PSME/CARU h.t., *AGSP* and *PIPO* phases; *PSME/SYAL* h.t., *AGSP* phase
PSME/CARU h.t., *CARU* phase; *PSME/CAGE* h.t.
PSME/SPBE; PSME/ARUV h.t.s
PSME/JUCO; PSME/ARCO h.t.s
PICEA/CLUN; PICEA/VACA h.t.s
PICEA/PHMA; PICEA/GATR; PICEA/LIBO; PICEA/SMST h.t.s
Abies grandis series
THPL/CLUN; TSHE/CLUN h.t.s
THPL/OPHO; ABLA/OPHO; PICEA/EQAR h.t.s
ABLA/CLUN; ABLA/GATR; ABLA/LIBO h.t.s
ABLA/VACA h.t.
ABLA/CACA h.t.
ABLA/MEFE; TSME/MEFE; ABLA/ALSI h.t.s
ABLA/XETE h.t., *VAGL* phase; *TSME/XETE; ABLA/VAGL* h.t.s
ABLA/XETE h.t., *VASC* phase; *ABLA/VASC* h.t., *ABLA/CAGE* h.t., *CAGE* phase
ABLA/CARU; ABLA/ARCO; ABLA/CAGE h.t., *PSME* phase
PICEA/SEST; ABLA/CLPS h.t.s
ABLA/LUHI; TSME/LUHI; ABLA-PIAL/VASC; ABLA/RIMO h.t.s
PIAL-ABLA; LALY-ABLA; PIAL h.t.s
Pinus contorta series

Other bases for groupings may be useful for various specialists in resource management. It is important to remember that such groupings (if used at all) should be made *after* a thorough inventory has been completed at the habitat type or phase level. Furthermore, every group should include a record of the relative amounts of each habitat type (and phase) within it; this will serve as a basis for general statements about the group.

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APPENDIXES

APPENDIX A

Number of sample plots by habitat type, phase, and National Forest in Montana. (c.t. = community type)

K = Kootenai National Forest
F = Flathead National Forest & west-side Glacier N.P.
WL = west Lolo National Forest (west of Missoula)
EL = east Lolo National Forest
B = Bitterroot National Forest
D = Deerlodge National Forest
BHD = Beaverhead National Forest
H = Helena National Forest
WLC = west Lewis and Clark National Forest and east-side Glacier N.P.
ELC = east Lewis and Clark National Forest (east of Choteau)
G = Gallatin National Forest and northern Yellowstone N.P.
C = Custer National Forest

	NATIONAL FOREST VICINITY												
HABITAT TYPE/PHASE	K	F	WL	EL	B	D	BHD	H	WLC	ELC	G	C	TOTAL
SCREE	.	.	2	4	3	.	.	4	2	1	.	.	16
PINUS FLEXILIS SERIES													
PIFL/AGSP	.	.	.	.	.	1	1	2	1	.	.	1	6
PIFL/FEID, FEID	.	.	.	.	.	.	2	2	1	.	1	1	7
/FEID, FESC	.	.	.	.	.	.	.	2	1	1		.	4
PIFL/JUCO	.	.	.	.	.	.	1	.	1	1	.	4	7
													24
PINUS PONDEROSA SERIES													
PIPO/AND	.	.	.	.	.	.	.	.	.	.	.	1	1
PIPO/AGSP	.	.	5	4	2	.	.	1	.	1	.	8	21
PIPO/FEID, FEID	.	.	1	2	6		.	1		.	.	4	14
/FEID, FESC	1	1	4	3	2	.	.	5	.	.	.	.	16
PIPO/PUTR, AGSP	.	.	.	1	2		.	1	.	.	.	.	4
/PUTR, FEID	2		1	1	1	.	.	2	.	.	.		7
PIPO/SYAL, SYAL	.	.	1	.	3	.	.	.	.	2	.	2	8
/SYAL, BERE	.	.	.	.	.	.	.	.	.	2	.	1	3
PIPO/PRVI, PRVI	.	.	.	.	.	.	.	.	.	.	.	6	6
/PRVI, SHCA	.	.	.	.	.	.	.	.	.	.		2	2
													82
PSEUDOTSUGA MENZIESII SERIES													
PSME/AGSP	.	1	.	.	1	4	.	3	.	2	1	1	13
PSME/FEID	1	.	.	.	.	3	12	.	.	.	2	1	19
PSME/FESC	2	3	.	2	.	.	.	6	.	.	.	.	13
PSME/VACA	8	2	5	5	2	1	.	2	1	1			27
PSME/PHMA, PHMA	2	4	9	10	7	3	1	3		.	2	4	45
/PHMA, CARU	.	.	2	2	4	.	.		.	.	.	.	8
PSME/VAGL, VAGL	.	1	1	4	.	.	1	3	.	2	1	.	13
/VAGL, ARUV	.	.	4	2	3	.	.	.	.	.	.	.	9
/VAGL, XETE	1	1	5	3	7	.		1	.	.	.	.	18
PSME/LIBO, SYAL	2	1	.	4	.	.	.	1	.	1	.	.	9
/LIBO, CARU	1	.	1	2	1	2	1	2	.	2	.	.	12
/LIBO, VAGL	.	.	3	2	2	1	.	.	.	1	.	.	9
PSME/SYAL, AGSP	.	1	1	1	4	.	.	2	.	.	.	.	9
/SYAL, CARU	2	6	1	6	10	1	3	4	.	1	6	.	40
/SYAL, SYAL	.	1	.	2	2	.	2	3	3	2	3	.	18
PSME/CARU, AGSP	2	1	2	2	3	.	.	.	.	.	.	.	10
/CARU, ARUV	2	.	.	2	5	.	.	2	.	.	.	.	11
/CARU, CARU	2	1		11	5	11	9	12	1	3	7	.	62
/CARU, PIPO	1	.	2	1	7	.	.	2	.	1	.	.	14
PSME/CAGE		.	.	3	.	.	1	2	.	2	1	1	10
PSME/SPBE	.	1	1	2	.	.	.	2	4	1	.	.	11
PSME/ARUV	.	.		.	.	.	.	3	.	4	.	1	8
PSME/JUCO	.		.	.	.	5	2	.	1	6	.	.	14
PSME/ARCO	.	.	.	.	.	2	5	4	.	2		.	13
PSME/SYOR		.	.	.	.	.	1	.	.	.	.		1
													416
PICEA SERIES													
PICEA/EQAR	.	3	.	.	.	.	1	1	2	1	1	.	9
PICEA/CLUN, VACA	1	7	.	.	.	.	.	.	.	.	.	.	8
/CLUN, CLUN	5	11	.	.	.	.	.	.	.	.	.	.	16
PICEA/PHMA	.		.	.	.	.	.	.	.	.	6	.	6
PICEA/GATR		.	.	1	1	1	1	1	.	1	9	.	15
PICEA/VACA	.	4	.	.	.	.	.	.	1	.	.	.	5
PICEA/SEST, PSME	.			.	.	.	2	.	1	2	.	.	5
PICEA/SEST, PICEA	.	.	.	.	.	.	.	.	.	5	.	.	5
PICEA/LIBO	.	.	.	1	.	2	2	.	.	5	11	.	21
PICEA/SMST	.	.	.	.	.	.	1	3	.	2	3	1	10
													100

(con.)

APPENDIX A (con.)

HABITAT TYPE/PHASE	NATIONAL FOREST VICINITY												
	K	F	WL	FL	B	D	BHD	H	WLC	ELC	G	C	TOTAL
ABIES GRANDIS SERIES													
ABGR/XETE	.	.	5	.	1	.	.	.	.	.		.	6
ABGR/CLUN, CLUN	1	1	2	.	2	.	.	.	.	.	.	.	6
/CLUN, ARNU	1	4		.	1		.	.	.	.	.		6
/CLUN, XETE	1	2	1	.	.	.	.	.	.	.	.		4
ABGR/LIBO, LIBO	.	1	2	.	2	.	.	.	.	.		.	5
/LIBO, XETE	.	.	3	.	.	.	.	.	.	.	.		3
													30
THUJA PLICATA SERIES													
THPL/CLUN, CLUN	3	6	5	1	.	.	.		.	.	.	.	15
/CLUN, ARNU	.	4	4	1	.		.	.	.	.	.		9
/CLUN, MEFE	1	2	3	1	.	.	.	.	.			.	7
THPL/OPHO	3	8	.	.	.	.	.	.	.	.	.	.	11
													42
TSUGA HETEROPHYLLA SERIES													
TSHE/CLUN, CLUN	8	19		.	.	.	.		.	.	.	.	27
/CLUN, ARNU	1	8	2	.	.	.	.	.	.			.	11
													38
ABIES LASIOCARPA SERIES													
Lower subalpine h.t.s													
ABLA/OPHO	1	3	.	.	.	.	.	.	.	.	.	.	4
ABLA/CLUN, CLUN	5	10	4	6	4	.	.	.	3	.	.	.	32
/CLUN, ARNU	.	12	.	2	2	.	.	.	2	.	.	.	18
/CLUN, VACA	.	8	.	1	1	.	.	.	.	.	.	.	10
/CLUN, XETE	1	8	7	4	.	.	.	.	1	.	.	.	21
/CLUN, MEFE	1	6	6	5	2	.	.	.	2	.	.	.	22
ABLA/GATR	.	.	2	1	4	2	.	4	4	2	15	.	34
ABLA/VACA	.	.	.	1	.	2	4	.	.	3	.	.	10
ABLA/CACA, CACA	.	.	.	.	6	2	8	.	.	1	5	1	23
/CACA, GATR	.	.	.	.	1	2	.	.	.	.	1	1	5
/CACA, VACA	.	3	.	.	.	2	1	.	.	1	.	.	7
ABLA/LIBO, LIBO	.	1	2	3	5	.	1	.	4	2	2	.	20
/LIBO, XETE	.	4	2	4	3	.	.	.	.	.	.	.	13
/LIBO, VASC	1	1	.	.	1	3	4	1	1	3	2	.	17
ABLA/MEFE	2	5	15	14	14	4	2	2	5		1	.	64
TSME/MEFE	1	.	8	1	.	.	.	.	.	.	.	.	10
ABLA/XETE, VAGL	4	6	11	4	11	.	1	.	3	.	.	.	40
/XETE, VASC	1	1	1	4	4	4	1	2	3	.	.	.	21
TSME/XETE	2	.	7	.	.	.	.	.	.	.	.	.	9
ABLA/VAGL	.	.	.	.	1	1	3	4	.	1	9	2	21
ABLA/VASC, CARU	.	.	.	.	.	1	2	1	.	1	4	1	10
/VASC, VASC	.	1	.	.	3	1	4	.	.	3	4	1	17
/VASC, THOC	.	.	.	.	.	2	3	.	.	1	4	.	10
ABLA/ALSI	.	.	.	.	1	1	1	.	1	.	2	.	6
ABLA/CARU	.	.	.	.	.	.	2	1	1	.	4	.	8
ABLA/CLPS	.	.	.	.	.	.	1	1	1	6	.	6	15
ABLA/ARCO	.	.	.	.	.	.	15	.	1	8	.	.	24
ABLA/CAGE, CAGE	.	.	.	.	.	.	.	.	.	2	1	.	3
/CAGE, PSME	.	.	.	.	.	.	1	.	.	2	3	.	6
Upper subalpine h.t.s													
ABLA/RIMO	.		.	.	.	.	3	.	.	.	.	3	6
ABLA-PIAL/VASC	.	.	.	.	3	4	12	2	3	7	10	3	44
ABLA/LUHI, VASC	1	3	1	3	11	3	2	1	4	.	.	.	29
/LUHI, MEFE	9	5	.	4	3	2	.	.	1	.	.	.	24
TSME/LUHI, VASC	.	.	2	.	.	.	.	.	.	.	.	.	2
/LUHI, MEFE	1	.	1	.	.	.	.	.	.	.	.	.	2
Timberline h.t.s													
PIAL-ABLA h.t.s	2	1	1	5	.	1	6	3	3	1	6	1	30
LALY-ABLA h.t.s	2	3	.	.	25	3	2	1	.	.	.	.	36
PIAL h.t.s	.	.	.	.	.	.	4	2	.	2	1		9
													682
PINUS CONTORTA SERIES													
PICO/PUTR h.t.	.	.	.	.	.	.	.	.	.	.	3	.	3
PICO/VACA c.t.	.	.	.	.	.	3	5	1	1	2	.	.	12
PICO/LIBO c.t.	.	1	.	.	2	6	2	.	.	2	4	.	17
PICO/VASC c.t.	.	1	.	.	3	5	4	3	.	2	1	1	20
PICO/CARU c.t.	.	.	.	.	.	1	3	.	.	1	1	.	6
													58*
UNCLASSIFIED STANDS (ecotonal, depauperate, or unusual communities)	3	3	6	1	6	1	2	6	3	6	4	2	43
Total Number of Plots*	91	189	154	149	200	87	138	116	66	109	137	60	1,496

* Thirty-five of the *Pinus contorta* community type plots were also listed under the corresponding *Pseudotsuga*, *Picea*, or *Abies lasiocarpa* h.t.s. These 35 were not counted twice in the "total number of plots" columns.

APPENDIX B

Distribution of tree species in Montana habitat types showing their dynamic status as interpreted from sample stand data

C = major climax species
S = major seral
a = accidentals

c = minor climax species
s = minor seral
( ) = in certain areas of the type

HABITAT TYPE-PHASE	JUSC	PIFL	PIPO	PSME	PICO	LAOC	PICEA	ABGR	PIMO	THPL	TSHE	ABLA	TSME	PIAL	LALY	BEPA
SCREE	.	(C)	(C)	C	a	.	.					(c)	.	(c)	.	.
PIFL/AGSP	(s)	C	s	a	.		.	.		.				.	.	.
PIFL/FEID, FEID	(s)	C	a	C	a	.	.	.		.	.	.		.	.	.
/FEID, FESC		C	a	C	a	.	.	.	.	.		.	.	.	.	.
PIFL/JUCO	a	C	a	s	a	.	a				.	a		(c)	.	.
PIPO/AND	c	.	C	.	.		.	.	.	.		.	.	.	.	.
PIPO/AGSP	(s)	a	C	a		.			.	.	.			.		.
PIPO/FEID, FEID	a	a	C	a	.	.	.	.		.	.	.	.	.		.
/FEID, FESC	a	a	C	a	.	.	.	.	.	.	.	.	.	.		.
PIPO/PUTR, AGSP	a	.	C	a		.	.	.		.	.	.	.	.	.	.
/PUTR, FEID	(s)	.	C	a	.	.	.	.			.	.	.	.	.	.
PIPO/SYAL, SYAL	a	a	C	a	.	.	.	.	.				.	.	.	.
/SYAL, BERE	a	a	C	a		.	.	.						.		.
PIPO/PRVI, PRVI	.	.	C	.	.		.	.	.					.	.	.
/PRVI, SHCA	a	.	C	.	.	.	.	.	.	.	.	.	.	.	.	.
PSME/AGSP	(s)	(s)	s	C			.				.			.	.	
PSME/FEID	a	a	a	C	.	.	.	.		.	.	.	.	.	.	.
PSME/FESC	a	(c)	s	C	.	.	.	.	.	.	.	.	.	.	.	.
PSME/VACA	.		(S)	C	S	(S)	a	.	.	.		a	.	.	.	
PSME/PHMA, PHMA		a	(s)	C	(s)	(s)	.	a	.	.	.	.	.	.	.	.
/PHMA, CARU		.	S	C	a	a	.	.	.	.	.	.	.	.	.	.
PSME/VAGL, VAGL	.	.	(s)	C	S	(s)	a		.	.	.	a	.	a	.	.
/VAGL, ARUV	.	.	S	C	(s)	(s)	.	a	.	.	.	.		.	.	.
/VAGL, XETE	.	.	(s)	C	S	(S)		a	.	.	.	a	.	a	.	.
PSME/LIBO, SYAL	.	.	(s)	C	(s)	(S)		.	.	.	.	.	.	.	.	.
/LIBO, CARU			(s)	C	(S)	(S)	.	.	.	.	.	a	.	.	.	.
/LIBO, VAGL		.	(s)	C	S	(s	a	a	.	.	.	a	.	.	.	.
PSME/SYAL, AGSP	.	a	S	C	.	.	.			.	.	.	.	.	.	.
/SYAL, CARU	.		(s)	C	(s)	a	a	.		.	.		.	.	.	.
/SYAL, SYAL		a	(S)	C	(s)	.	.	.	.	.	.	.	.	a	.	.
PSME/CARU, AGSP		.	S	C	.	.	.	.	.	.	.	.	.	.	.	.
/CARU, ARUV		.	S	C	s	(s)	.	.	.	.	.	.	.	.	.	.
/CARU, CARU		.	a	C	(S)	(s	.	.	.	.	.	a	.	a	.	.
/CARU, PIPO	.	.	S	C	.	.	.	.	.	.	.	.	.	.	.	.
PSME/CAGE	.	a	(s	C	a	.	.	.	.		.	a	.	(c)	.	.
PSME/SPBE		a	(S)	C	a	a	.	.	.	.	.	.	.	.	.	.
PSME/ARUV	.	s	S	C	a	.	.	.	.	.	.	.	.	.	.	.
PSME/JUCO		(s)	a	C	S	.	a	.	.	.	.	a	.	a	.	.
PSME/ARCO	.	(s	a	C	a	.	.	.	.	.	.	.	.	.	.	.
PSME/SYOR	(c)	(c)	.	C	.	.	.	.	.	.	.	.	.	.	.	.
PICEA/EQAR		.	.	a	a	.	C	.	.	.	.	a	.	.	.	(s)
PICEA/CLUN, VACA	.	.	(s)	S	S	S	C	.	a	.	.	a	.	.	.	.
/CLUN, CLUN		.	(s	S	(S)	S	C	.	a	.	.	a	.	.	.	(S)
PICEA/PHMA	.	.	.	S	(S)		C	.	.	.	.	(c)	.	a	.	.
PICEA/GATR	.	.	(s)	S	S	.	C	.	.	.	.	a	.	a	.	.
PICEA/VACA		.	(s)	S	S	S	C		.	.	.	a	.	.	.	.
PICEA/SEST, PSME	.	s	.	S		.	C	.	.	.	.	a	.	a	.	.
/SEST, PICEA		.	.	a	.		C	.	.	.	.	a	.	a	.	.
PICEA/LIBO		.	a	S	S		C	.	.	.	.	a	.	a	.	.
PICEA/SMST	.	.	(s)	S	S	.	C	.	.	.	.	a	.	a	.	.
ABGR/XETE	.	.	s	S	S	S	a	C	a	a	.	a	.	.	.	.
ABGR/CLUN, CLUN	.	.	(s)	S	(s	(s)	(s)	C	(s)	a	.	(c)	.	.	.	.
/CLUN, ARNU	.		a	S	a	S	S	C	(s)	a	a	a	.	.	.	s
/CLUN, XETE	.	.	a	S	s	S	(S)	C	s	a	a	c	.	.	.	a
ABGR/LIBO, LIBO	.		(s)	S	s	S	a	C	.	.	.	a	.	.	.	a
/LIBO, XETE	.	.	(s)	S	s	s	a	C	.	.	.	.	.	.	.	.
THPL/CLUN, CLUN	.		a	S	(s)	S	S	(c)	(s)	C	a	(c)	.	.	.	(s)
/CLUN, ARNU	.	.	.	S	a	S	(S)	(c)	(s)	C	(c)	(s)	.	.	.	(s)
/CLUN, MEFE	.	.	.	s	S	S	S	a	(s)	C	.	c	.	.	.	.
THPL/OPHO	.	.	.	s	.	a	s	(s)	a	(C)	(C)	(c)	.	.	.	(s)
TSHE/CLUN, CLUN	.	.	a	S	(s)	S	s	(s)	S	c	C	(c)	.	.	.	(s)
/CLUN, ARNU	.	.	a	(s)	a	S	(S)	(c)	.	c	C	(c)	.	.	.	(s)
ABLA/OPHO	.	.	.	s	.	s	S	.	s	.	a	C	.	.	.	.
ABLA/CLUN, CLUN	.	.	s	S	(S)	S	S	(s)	(s	a	a	C	.	a	.	■
/CLUN, ARNU	.	.	a	s	(s)	s	S	(s)	(S)	.	a	C	.	.	.	(S)
/CLUN, VACA	.	.	s	S	S	s	s	a	a	.	.	C	.	a	.	.
/CLUN, XETE	.	.	.	S	S	S	S	a	(s)	.	a	C	(c)	a	.	.
/CLUN, MEFE	.	.	.	S	s	s	S	(C)	(s)	a	a	C	(c)	a	.	.
ABLA/GATR	.		a	S	S	(s)	S	.	.	.	.	C	.	.	.	.
ABLA/VACA	.			s	S	a	(c		.	.		c	.	a	.	.
ABLA/CACA, CACA	.			.	S	.	S		.	.		C	.	(s)	.	.
/CACA, GATR	.	.		.	s	.	S		.	.	.	C	.	.	.	.
/CACA, VACA	.		.	a	s	.	s	.	.	.	.	C	.	a	.	.
ABLA/LIBO, LIBO	.	a	s	s	S	(S)	S	a	.	.	.	C	.	a	.	.
/LIBO, XETE		.	a	S	S	S	s	a	(s)	.	.	C	.	.	.	.
/LIBO, VASC		a	.	s	S	a	s	.	.	.	.	C	.	a	.	.
ABLA/MEFE	.		.	(S)	S	(s)	S	a	a	.	.	C	a	(s)	.	.
TSME/MEFE		.		s	s	s	s	.	(s)	.	.	C	C	(s)	.	.
ABLA/XETE, VAGL			s	s	s	(s)	s	a	(s)		.	C	a	(s)	.	.
/XETE, VASC	.			(s)	S	.	s	.	.	.	.	C	a	(s)	.	.
TSME/XETE			.	s	s	(s)	s	a	(s		.	C	C	(s)	.	.
ABLA/VAGL		a		S	S	.	S	.	.	.	.	C	.	(s)	.	.
ABLA/VASC, CARU		.		S	S		s	.	.		.	C	.	a	.	.
/VASC, VASC	.	.	.	a	S		(s	.	.	.	.	C	.	s	.	.
/VASC, THOC			.	a	S	.	S	.	.	.	.	C	.	a	.	.
ABLA/ALSI		.	.	(S)	S		S		.	.		C	.	(s)	.	.
ABLA/CARU	.	.	.	S	S	.	s	.		.	.	C	.	a	.	.
ABLA/CLPS		s	.	S	(s)		S	.	.	.	.	C	.	(S)	.	.
ABLA/ARCO				S	S	.	S	.				C	.	(s)	.	.
ABLA/CAGE, CAGE	.	a	.	a	(S)	.	a	.	.	.	.	C	.	(s)	.	.
/CAGE, PSME	.	.	.	s	a	.	a	.	.	.	.	C	.	.	.	.
ABLA/RIMO		.	.	.	.		(S)	.		.	.	C	.	(S)	.	.
ABLA-PIAL/VASC	.	.	.	.	(S)		S	.	.	.	.	C	.	S	.	.
ABLA/LUHI, VASC		.	.	.	(s)	.	S		.		.	C	a	S	.	.
/LUHI, MEFE		.	.	.	a	.	S	.	.	.	.	C	.	s	(C)	.
TSME/LUHI, VASC		.	.	.	(s)	.	s	.	.	.	.	C	C	s	.	.
/LUHI, MEFE	.	.	.	.	a	.	s	.	.	.	.	(C)	C	a	.	.
PIAL-ABLA h.t.s	.	.	.	.	.	.	(C)	.	.	.	.	(C)	.	(C)	.	.
LALY-ABLA h.t.s	.		.	.	.	.	(C)	.		.	.	(C)	.	(C)	(C)	.
PIAL h.t.s	.	a	.	a	.	.	a	.	.	.	.	a	.	C	.	.

APPENDIX [illegible]

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in Montana forest habitat types and phases

	"SCREE"	PINUS FLEXILIS SERIES				PINUS PONDEROSA SERIES							
		AGSP h.t.	FEID h.t.		JUCO h.t.	AGSP h.t.	FEID h.t.		PUTR h.t.		SYAL h.t.		PRVI h.t.
			FEID phase	FESC phase			FEID phase	FESC phase	AGSP phase	FEID phase	SYAL phase	BERE phase	PRVI phase
No. of stands	16	6	7	1	7	21	14	16	4	7	5	[illegible]	6
TREES													
Juniperus scopulorum	4(8)	5(30)	4(14)	-(0)	3(2)	3(1)	4(3)	4(1)	3(3)	4(1)	3(1)	3(1)	[illegible]
Pinus flexilis	5(29)	1(8)	10(5)	1(41)	1(4)	+	[illegible]	1(1)	(0)	[illegible]	(3)	3(1)	[illegible]
Pinus ponderosa	6(1)	[illegible]	1(3)	[illegible]	1( )	1(7)	10(59)	10(59)	10(38)	(46)	10( )	10(54)	10(
Fraxinus pennsylvanica	(1)	-( )	( )	(0)	-( )	[illegible]	(0)	(0)	0)	0)	0)	-(0)	7(1)
Pseudotsuga menziesii	1(20)	(2)	1(17)	(3)	(1)	3( )	3( )	1(1)	(0)	-(0)	5( )	3(1)	[illegible]
Pinus contorta	1(1)	-( )	1(0)	( )	1(1)	+( )	[illegible]	(0)	[illegible]	(0)	1(0)	-(0)	[illegible]
Larix occidentalis	( )	( )	( )	-( )	( )	( )	[illegible]	(0)	(0)	(0)	(0)	-(0)	[illegible]
Pinus monticola	(0)	( )	(0)	( )	(0)	( )	(0)	(0)	[illegible]	(0)	[illegible]	[illegible]	[illegible]
Picea glauca	1(1)	( )	( )	( )	1( )	[illegible]	[illegible]	[illegible]	(0)	(0)	-(0)	-(0)	-( )
Picea engelmannii	1(1)	( )	( )	( )	1(1)	-( )	(0)	(0)	[illegible]	(0)	( )	-(0)	[illegible]
Betula papyrifera	( )	(0)	( )	( )	( )	-( )	( )	[illegible]	(0)	[illegible]	(0)	-(0)	[illegible]
Abies grandis	-( )	( )	( )	-( )	[illegible]	[illegible]	(0)	(0)	(0)	(0)	(0)	-(0)	-( )
Thuja plicata	-( )	(0)	(0)	( )	-( )	(0)	[illegible]	(0)	(0)	[illegible]	(0)	-(0)	[illegible]
Tsuga heterophylla	( )	-(0)	(0)	( )	[illegible]	( )	(0)	(0)	(0)	(0)	[illegible]	[illegible]	[illegible]
Abies lasiocarpa	2(1)	[illegible]	(0)	-( )	1(0)	( )	-( )	(0)	( )	0	( )	-(0)	[illegible]
Tsuga mertensiana	-(0)	( )	(0)	( )	( )	( )	[illegible]	(0)	( )	(0)	-(0)	[illegible]	[illegible]
Pinus albicaulis	1(15)	(0)	( )	( )	1(1)	[illegible]	-( )	[illegible]	(0)	(0)	(0)	-(0)	[illegible]
Larix lyallii	(0)	-(0)	(0)	( )	-(0)	-(0)	-( )	[illegible]	(0)	(0)	(0)	-(0)	-(0)
SHRUBS AND SUBSHRUBS													
Alnus sinuata	(0)	(0)	-(0)	(0)	( )	(0)	[illegible]	[illegible]	(0)	[illegible]	-(0)	-(0)	[illegible]
Amelanchier alnifolia	6(8)	2(1)	4(1)	3(1)	1(1)	5(1)	7(1)	6(2)	8(5)	4(1)	(4)	7(1)	10(16)
Artemisia tridentata	(0)	5(1)	(1)	-(0)	1(1)	+(3)	(0)	(0)	(0)	(0)	(0)	-(0)	(0)
Holodiscus discolor	-(0)	(0)	-(0)	-( )	( )	[illegible]	( )	-( )	( )	(0)	[illegible]	-(0)	-( )
Juniperus communis	4(14)	2(1)	6(5)	8(11)	9(28)	+(1)	1(1)	1(1)	(0)	(0)	1(3)	10(5)	-( )
Juniperus horizontalis	1(3)	-(1)	1(37)	5(2)	5(26)	( )	(0)	(0)	(0)	(0)	( )	-(0)	( )
Ledum glandulosum	(0)	( )	(0)	(0)	(0)	( )	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-( )
Menziesia ferruginea	(0)	(0)	-(0)	-( )	-(0)	-( )	-( )	(0)	-(0)	[illegible]	(0)	-(0)	( )
Oplopanax horridum	( )	( )	-(0)	-( )	-( )	-( )	-(0)	-(0)	(0)	(0)	-(0)	-(0)	( )
Pachistima myrsinites	(0)	( )	(0)	-( )	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Phyllodoce empetriformis	(0)	-( )	( )	( )	-(0)	-( )	[illegible]	-(0)	(0)	( )	(0)	-(0)	-(0)
Physocarpus malvaceus	2(10)	( )	1(1)	( )	1(5)	-( )	1(0)	1(5)	3(3)	-(0)	-(0)	-(0)	(0)
Prunus virginiana	4(2)	3(0)	(1)	( )	(0)	3(3)	3(1)	3(2)	5(1)	3(26)	6(1)	10(1)	10(34)
Purshia tridentata	(0)	( )	1(3)	( )	-(0)	-( )	1(1)	(1)	10(26)	10(28)	1(1)	-(0)	(0)
Ribes lacustre	-(0)	2(1)	(0)	( )	(0)	( )	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)
Ribes montigenum	-(0)	( )	(0)	( )	1(1)	( )	(0)	(0)	-(0)	-(0)	(0)	-(0)	-(0)
Rubus parviflorus	-(0)	-( )	-(0)	( )	(0)	(0)	(0)	-(0)	(0)	(0)	-(0)	-(0)	(0)
Shepherdia canadensis	3(2)	( )	1(1)	8(1)	6(2)	1(1)	(0)	1(3)	(0)	(0)	1(1)	3(3)	(1)
Spiraea betulifolia	5(4)	(0)	1(1)	5(1)	3( )	+(1)	1(1)	1(2)	-(0)	1(3)	1(3)	7(15)	[illegible]
Symphoricarpos albus	4(5)	2(1)	4(1)	(0)	3(8)	7(1)	4(1)	4(4)	5(2)	-( )	10(47)	10(18)	10(13)
Taxus brevifolia	-(0)	-( )	-(0)	( )	-( )	(0)	(0)	(0)	(0)	-(0)	(0)	-(0)	(0)
Vaccinium caespitosum	(0)	-(0)	-(0)	-(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	-(0)	-(0)
Vaccinium globulare	1(3)	( )	(0)	(0)	-(0)	(0)	(0)	(0)	(0)	-(0)	(0)	-(0)	(0)
Vaccinium myrtillus	-( )	-( )	-(0)	-(0)	(0)	(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vaccinium scoparium	(0)	(0)	(0)	( )	-(0)	( )	(0)	(0)	-(0)	-(0)	(0)	-(0)	( )
Arctostaphylos uva-ursi	4(9)	( )	5(2)	8(14)	4(18)	+(15)	( )	1(2)	(0)	1(1)	(0)	3(1)	2(0)
Berberis repens	1(0)	(0)	3(1)	( )	4(1)	+(1)	2(6)	-(0)	3(1)	-(0)	4(1)	10( )	10(20)
Linnaea borealis	-(0)	(0)	(0)	( )	( )	-( )	-(0)	( )	-(0)	-(0)	-(0)	-(0)	-( )
FERNS AND FERN ALLIES													
Athyrium filix-femina	(0)	( )	-( )	(0)	(0)	-( )	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	( )
Equisetum arvense	(0)	(0)	(0)	(0)	(0)	-(0)	(0)	(0)	(0)	(0)	-( )	-(0)	-(0)
Gymnocarpium dryopteris	-(0)	-(0)	-( )	-( )	-(0)	( )	( )	(0)	(0)	( )	(0)	-(0)	(0)
GRAMINOIDS													
Agrostis scabra	-(0)	-(0)	-(0)	-( )	-(0)	-( )	(0)	(0)	(0)	-(0)	(0)	-(0)	10(6)
Agropyron spicatum	8(7)	10(20)	9(8)	8( )	5(2)	10(28)	7(8)	9(20)	10(15)	7(28)	8(12)	3(3)	2(1)
Calamagrostis canadensis	(0)	-(0)	( )	( )	( )	( )	( )	(0)	-(0)	-(0)	-(0)	-(0)	(0)
Calamagrostis rubescens	1(2)	(0)	-(0)	( )	(0)	-( )	1(1)	-(0)	(0)	-(0)	(0)	-(0)	-( )
Carex geyeri	5(3)	(0)	1(1)	(0)	-( )	1(1)	2(1)	1(1)	-(0)	( )	1(15)	-(0)	-( )
Festuca idahoensis	4(1)	5(1)	10(25)	10(23)	4(0)	4(2)	10(21)	9(12)	8(1)	7(23)	6(18)	7(1)	7(1)
Festuca scabrella	3(1)	2(1)	3(1)	10(21)	(0)	1(1)	1(1)	10(18)	-(0)	9(16)	3(1)	-(0)	-(0)
Hesperochloa kingii	1(1)	3(15)	1(3)	(0)	4(1)	( )	( )	(0)	(0)	-(0)	-(0)	-(0)	-( )
Luzula hitchcockii	-(0)	-(0)	(0)	(0)	(0)	(0)	(0)	(0)	-(0)	-(0)	(0)	-(0)	-( )
Oryzopsis asperifolia	(0)	(0)	( )	( )	( )	( )	-(0)	(0)	(0)	-(0)	(0)	-(0)	( )
Schizachne purpurascens	(0)	-( )	( )	(0)	-(0)	-(0)	-(0)	-(0)	(0)	(0)	(0)	7(0)	8(4)
FORBS													
Actaea rubra	-(0)	-(0)	(0)	-( )	(0)	(0)	( )	(0)	(0)	-(0)	(0)	-(0)	( )
Adenocaulon bicolor	(0)	-( )	( )	[illegible]	( )	-(0)	(0)	-(0)	-(0)	(0)	(0)	-(0)	( )
Aralia nudicaulis	-(0)	(0)	( )	-(0)	-(0)	(0)	(0)	(0)	-(0)	-(0)	(0)	-(0)	( )
Arnica cordifolia	1(1)	-( )	1(1)	( )	6(1)	( )	( )	( )	(0)	(0)	1(3)	-(0)	10(1)
Arnica latifolia	(0)	( )	(0)	( )	( )	( )	(0)	-(0)	(0)	-(0)	-( )	-(0)	(0)
Balsamorhiza sagittata	5(2)	2(3)	4(5)	5(20)	1(0)	7(7)	8(1)	4(8)	10(1)	7(11)	8(8)	10(1)	5( )
Clematis pseudoalpina	1(1)	( )	( )	-( )	+(1)	[illegible]	(0)	1(1)	-(0)	-(0)	1(0)	7(2)	( )
Clematis tenuiloba	(0)	-(0)	(0)	( )	3(1)	+(1)	(0)	( )	-(0)	-(0)	1( )	3(1)	( )
Clintonia uniflora	-(0)	-(0)	-( )	-( )	-( )	-( )	(0)	(0)	-( )	(0)	(0)	-(0)	( )
Coptis occidentalis	-(0)	2(1)	-( )	( )	-(0)	-(0)	(0)	(0)	-(0)	(0)	(0)	-(0)	-(0)
Cornus canadensis	(0)	( )	( )	( )	-(0)	( )	( )	(0)	-(0)	( )	(0)	-(0)	-( )
Disporum trachycarpum	-( )	-( )	(0)	( )	( )	(0)	(0)	-(0)	( )	-(0)	1(1)	3(1)	1(1)
Galium boreale	2(1)	2(1)	5(1)	10(1)	9( )	1(1)	( )	1(2)	( )	-(0)	4(1)	10(1)	10(1)
Galium triflorum	-( )	( )	(0)	( )	-(0)	-( )	(0)	1(1)	( )	( )	(0)	-(0)	(0)
Geranium richardsonii	(0)	( )	( )	( )	(0)	(0)	(0)	(0)	-(0)	-(0)	(0)	-(0)	-( )
Hieracium gracile	(0)	-( )	(0)	( )	(0)	[illegible]	-(0)	-( )	(0)	( )	-(0)	-(0)	( )
Osmorhiza chilensis	1(1)	(0)	(0)	-( )	1(1)	( )	(0)	(0)	(0)	-(0)	1(1)	7(2)	2(1)
Pyrola asarifolia	-(0)	(0)	(0)	( )	(0)	(0)	-(0)	-(0)	(0)	(0)	[illegible]	-(0)	( )
Pyrola secunda	-( )	( )	( )	3(1)	1(1)	( )	( )	-(0)	( )	(0)	( )	-(0)	( )
Pyrola uniflora	(0)	( )	(0)	( )	-( )	( )	(0)	(0)	(0)	(0)	(0)	-(0)	( )
Senecio streptanthifolius	-(0)	( )	(0)	-( )	7(1)	-( )	(0)	-(0)	(0)	(0)	(0)	-(0)	(0)
Senecio triangularis	-(0)	(0)	( )	( )	(0)	( )	(0)	( )	(0)	( )	(0)	( )	( )
Smilacina racemosa	2(1)	(0)	(0)	(0)	( )	+(1)	1(1)	(0)	2(1)	-(0)	-(0)	3(1)	(1)
Smilacina stellata	1(1)	( )	(0)	( )	7(1)	+(1)	(0)	(0)	-(0)	( )	1(1)	7(1)	3(2)
Streptopus amplexifolius	-(0)	( )	( )	(0)	-(0)	(0)	(0)	-(0)	( )	(0)	(0)	-(0)	-( )
Thalictrum occidentale	1(1)	(0)	( )	( )	(1)	[illegible]	-( )	[illegible]	(0)	-(0)	( )	-(0)	(1)
Tiarella trifoliata	( )	-(0)	(0)	( )	(0)	(0)	(0)	(0)	(0)	(0)	( )	( )	( )
Trollius laxus	-( )	( )	-( )	(0)	( )	-( )	(0)	(0)	(0)	-(0)	[illegible]	-(0)	-( )
Valeriana sitchensis	-(0)	( )	( )	(0)	-( )	( )	(0)	(0)	( )	(0)	(0)	-(0)	( )
Veratrum viride	-( )	(0)	[illegible]	( )	( )	( )	-(0)	(0)	(0)	(0)	(0)	-(0)	-( )
Viola canadensis	-( )	-( )	[illegible]	-( )	( )	(0)	-(0)	(0)	(0)	(0)	( )	-(0)	2(1)
Viola orbiculata	(0)	-( )	(0)	( )	(0)	(0)	-(0)	(0)	-(0)	(0)	(0)	-(0)	( )
Xerophyllum tenax	1(1)	( )	[illegible]	( )	( )	-( )	(0)	-(0)	(0)	-(0)	( )	-(0)	( )

*Code to constancy values: + = 0-5%, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%.

(con.)

	AGSP h.t.	[illegible] h.t.	[illegible] h.t.	[illegible] h.t.	[illegible] h.t.		VAGL h.t			LIBO h.t.			SYAL h.t		
					PHMA phase	CARU phase	VAGL phase	ARUV phase	XETE phase	SYAL phase	CARU phase	VAGL phase	AGSP phase	CARU phase	SYAL phase
[illegible]	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	[illegible]	[illegible]	[illegible]	9	40	18
TREES															
[illegible]	7(7)	6(2)	3(1)	+(1)	2(4)	1(3)	-(0)	-(0)	[illegible]	[illegible]	1(1)	-(0)	2(1)	2(7)	[illegible]
[illegible]	3(5)	2(0)	2(8)	-(0)	1(21)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	1(15)	[illegible]	3(3)
[illegible]	[illegible]	2(0)	8(26)	7(31)	6(8)	10(28)	[illegible]	10(29)	3(3)	4(10)	3(8)	6(14)	8(24)	6(27)	3(61)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	10(34)	[illegible]	10(35)	10(23)	10(58)	10(32)	10(35)	10(30)	10(46)	10(62)	10(41)	10(42)	10(41)	10(50)	9(55)
[illegible]	-(0)	-(0)	[illegible]	8(29)	2(7)	3(2)	9(37)	[illegible]	9(27)	[illegible]	7(30)	9(17)	-(0)	3(16)	2(13)
[illegible]	-(0)	-(0)	-(0)	7(12)	2(8)	3(0)	[illegible]	6(4)	3(20)	4(18)	3(31)	6(11)	-(0)	[illegible]	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	+(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	+(0)	[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	3(0)	1(1)	-(0)	[illegible]	1(0)
Bet[illegible]	-(0)	-(0)	-(0)	-(0)	+(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)
Abie gran	-(0)	-(0)	-(0)	-(0)	1(1)	1(0)	[illegible]	[illegible]	[illegible]	-(0)	[illegible]	1(1)	-(0)	[illegible]	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	[illegible]	-(0)	[illegible]	2(1)	+(0)	-(0)	2(1)	1(1)	5(0)	[illegible]	4(1)	6(0)	-(0)	+(0)	1(1)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	[illegible]	-(0)	[illegible]	+(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	-(0)	1(0)	2(1)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
SHRUBS AN[illegible]															
Alnu sinu	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	1(1)	-(0)	2(3)	-(0)	-(0)	-(0)	-(0)
Amel alni	3(4)	1(0)	7(3)	8(4)	[illegible]	8(3)	6(1)	8(1)	4(6)	9(5)	4(3)	8(1)	[illegible]	7(6)	4(3)
Arte tri[illegible]	1(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)
Holo disc	-(0)	-(0)	-(0)	1(20)	2(18)	-(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	2(8)	1(2)	[illegible]
[illegible] comm	2(2)	2(1)	3(1)	2(1)	[illegible]	-(0)	4(7)	[illegible]	1(1)	1(3)	5(7)	[illegible]	-(0)	3(6)	6(6)
[illegible] hor.	-(0)	1(15)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(6)
Ledu glan	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Menz ferr	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	-(0)
Oplo horr	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pach myrs	-(0)	-(0)	-(0)	1(3)	[illegible]	-(0)	3(4)	1(1)	4(6)	1(1)	1(1)	-(0)	-(0)	1(2)	-(0)
Phyl empe	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Phys malv	-(0)	-(0)	-(0)	+(1)	9(51)	10(21)	[illegible]	[illegible]	[illegible]	2(2)	3(3)	[illegible]	2(3)	[illegible]	[illegible]
Prun virg	2(2)	[illegible]	5(2)	-(0)	2(4)	3(3)	-(0)	-(0)	[illegible]	-(0)	[illegible]	-(0)	2(2)	4(3)	6(3)
Purs trid	3(0)	[illegible]	2(43)	1(23)	1(1)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(13)	1(1)
Ribe lacu	-(0)	1(1)	5(2)	-(0)	[illegible]	3(-)	1(1)	-(0)	[illegible]	2(2)	3(1)	-(0)	-(0)	4(3)	6(3)
Ribe mont	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)
Rubu parv	-(0)	-(0)	-(0)	-(0)	1(2)	-(0)	[illegible]	-(0)	[illegible]	2(1)	[illegible]	-(0)	-(0)	-(0)	-(0)
Shep cana	3(1)	-(0)	[illegible]	4(3)	2(1)	3(2)	5(1)	2(2)	[illegible]	4(1)	3(1)	8(1)	2(1)	2(4)	4(1)
Spir betu	[illegible]	-(0)	2(1)	8(14)	8(5)	9(6)	9(13)	9(9)	[illegible]	10(11)	[illegible]	10(7)	3(7)	8(11)	7(18)
Symp albu	5(3)	[illegible]	[illegible]	6(10)	[illegible]	9(6)	2(3)	4(2)	2(2)	10(28)	[illegible]	[illegible]	10(20)	10(34)	10(20)
Taxu brev	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vacc caes	-(0)	-(0)	-(0)	10(14)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vacc glob	-(0)	-(0)	-(0)	2(12)	1(10)	[illegible]	10(29)	10(36)	8(37)	4(1)	3(1)	10(28)	-(0)	-(0)	1(3)
Vacc myrt	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(8)	[illegible]	-(0)	-(0)	-(0)
Vacc scop	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	4(28)	[illegible]	2(35)	-(0)	4(41)	6(9)	-(0)	-(0)	1(1)
Arct uva-	[illegible]	-(0)	1(1)	8(36)	2(3)	8(19)	1(1)	10(25)	1(1)	6(9)	5(14)	[illegible]	[illegible]	3(3)	4(10)
Berb repe	2(1)	1(1)	3(5)	[illegible]	[illegible]	[illegible]	7(2)	9(2)	6(2)	10(5)	[illegible]	9(1)	7(1)	9(4)	9(3)
Linn bore	-(0)	-(0)	[illegible]	5(15)	[illegible]	1(1)	2(1)	-(0)	1(15)	[illegible]	10(26)	10(15)	-(0)	-(0)	1(0)
FERNS AND FERN ALLIES															
Athy fili	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Equi arve	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Gymn dry[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
GRAMINOIDS															
Agro scab	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)
Agro spic	10(25)	[illegible]	9(19)	-(0)	2(3)	5(4)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	8(16)	[illegible]	4(1)
Cala cana	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
Cala rube	[illegible]	2(1)	3(2)	10(30)	[illegible]	10(20)	9(12)	10(20)	10(24)	10(18)	10(30)	10(33)	4(29)	10(26)	7(2)
Care geye	2(1)	2(6)	2(6)	6(15)	5(8)	10(11)	7(7)	[illegible]	6(5)	7(4)	6(3)	3(6)	4(8)	8(12)	6(1)
Fest idah	5(1)	10(12)	8(21)	[illegible]	1(1)	4(1)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	[illegible]	2(1)	2(1)
Fest scab	2(1)	-(0)	10(20)	3(1)	[illegible]	[illegible]	1(1)	-(0)	-(0)	-(0)	1(1)	-(0)	4(11)	[illegible]	2(1)
Hesp king	1(1)	2(1)	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Luzu hitc	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)
Oryz aspe	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Schi purp	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
FORBS															
Acta rubr	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)
Aden bico	-(0)	-(0)	-(0)	1(1)	1(1)	-(0)	-(0)	[illegible]	1(1)	-(0)	-(0)	-(0)	-(0)	1(8)	-(0)
Aral nudi	-(0)	-(0)	-(0)	-(0)	+(2)	-(0)	-(0)	-(0)	-(0)	1(37)	-(0)	-(0)	-(0)	[illegible]	-(0)
Arni cord	1(1)	3(1)	4(4)	6(4)	8(8)	5(2)	6(9)	9(9)	6(5)	8(18)	7(10)	6(15)	[illegible]	7(8)	4(3)
Arni lati	-(0)	[illegible]	1(1)	[illegible]	[illegible]	-(0)	4(27)	[illegible]	[illegible]	[illegible]	5(14)	6(19)	-(0)	[illegible]	1(1)
Bals sagi	7(21)	3(10)	8(13)	[illegible]	1(1)	5(4)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	6(15)	4(1)	4(1)
[illegible]	-(0)	-(0)	[illegible]	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	1(3)	2(3)	-(0)	-(0)	-(0)	1(3)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	[illegible]	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Copt occi	-(0)	-(0)	-(0)	-(0)	+(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Corn cana	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	1(1)	1(1)	[illegible]	7(2)	3(1)	3(1)	-(0)	1(1)	[illegible]	3(1)	1(1)	[illegible]	4(1)	6(4)
Gali bore	3(1)	2(1)	[illegible]	3(1)	2(1)	-(0)	2(1)	[illegible]	-(0)	4(1)	4(1)	-(0)	1(1)	3(0)	4(1)
Gali trif	-(0)	-(0)	-(0)	1(1)	[illegible]	-(0)	[illegible]	-(0)	-(0)	[illegible]	[illegible]	1(1)	-(0)	[illegible]	2(1)
Gera r[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Hier [illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	[illegible]	1(1)	[illegible]	2(1)	4(1)	[illegible]	5(1)	1(1)	4(1)	8(3)	3(1)	-(0)	1(1)	5(1)	4(1)
[illegible]	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	1(1)	-(0)	-(0)	[illegible]	2(1)	2(1)	-(0)	-(0)	-(0)
Pyro secu	-(0)	-(0)	-(0)	[illegible]	1(1)	-(0)	8(1)	-(0)	2(1)	7(1)	8(1)	6(1)	-(0)	[illegible]	1(1)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Sene stre	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	+(1)	1(1)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]
[illegible]	[illegible]	-(0)	[illegible]	2(1)	6(1)	4(1)	5(1)	2(1)	2(2)	7(1)	[illegible]	2(1)	2(2)	5(2)	4(4)
Smil stel	1(1)	-(0)	-(0)	[illegible]	2(1)	[illegible]	2(1)	-(0)	-(0)	4(1)	2(2)	-(0)	-(0)	2(2)	2(1)
Stre ampl	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Thal occi	[illegible]	-(0)	[illegible]	3(3)	6(2)	-(0)	5(9)	-(3)	4(3)	9(9)	5(10)	3(1)	-(0)	5(7)	6(1)
Tiar trif	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]
[illegible]	-(0)	-(0)	[illegible]	1(1)	-(0)	-(0)	2(2)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Viol cana	-(0)	-(0)	[illegible]	-(0)	+(1)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)
Viol orbi	-(0)	-(0)	-(0)	+(1)	[illegible]	-(0)	-(0)	-(0)	1(1)	2(1)	2(2)	[illegible]	-(0)	[illegible]	1(3)
Xero tena	-(0)	-(0)	-(0)	2(14)	1(8)	-(0)	2(1)	9(13)	[illegible]	1(1)	2(2)	7(11)	-(0)	1(2)	-(0)

con

APPENDIX C (con.)

(See instructions for use on page [illegible])

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in Montana forest habitat types and phases

	PSEUDOTSUGA MENZIESII SERIES (con.)									PICEA SERIES					
	CARU h.t.				CAGE h.t.	SPBE h.t.	ARUV h.t.	JUCO h.t.	ARCO h.t.	EQAR h.t.	CLUN h.t.		PIMA h.t.	GAIR h.t.	VACA h.t.
	AGSP phase	ARUV phase	CARU phase	PIPO phase							VACA phase	CLUN phase			
No. of Stands	10	11	62	14	10	11	8	14	17	9	8	16	6	15	5
TREES															
Juni scop	2(2)	2(0)	1(1)	-(0)	2(2)	4(1)	6(1)	1(0)	2(3)	-(0)	-(0)	-(0)	-(0)	1(1)	2(1)
Pinu flex	-(0)	-(0)	+(1)	-(0)	1(1)	2(1)	6(3)	4(0)	3(2)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pinu pond	10(45)	10(36)	2(1)	10(37)	3(13)	5(27)	10(32)	1(8)	2(8)	-(0)	4(5)	1(8)	-(0)	1(39)	2(15)
Frax penn	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pseu menz	10(18)	10(26)	10(60)	10(42)	10(74)	10(60)	10(43)	10(32)	10(63)	4(1)	8(11)	8(19)	10(50)	7(13)	8(11)
Pinu cont	1(0)	9(8)	6(20)	-(0)	3(1)	3(5)	1(15)	9(31)	1(3)	4(5)	10(21)	4(22)	3(25)	6(19)	10(34)
Lari occi	-(0)	3(1)	1(11)	-(0)	-(0)	2(0)	-(0)	-(0)	-(0)	-(0)	6(7)	7(20)	-(0)	-(0)	8(15)
Pinu mont	-(0)	1(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(2)	1(3)	-(0)	-(0)	-(0)
Pice glau	-(0)	-(0)	+(1)	-(0)	1(1)	1(0)	1(1)	1(0)	-(0)	6(71)	8(21)	8(32)	5(18)	3(53)	6(11)
Pice enge	-(0)	-(0)	+(0)	-(0)	-(0)	-(0)	-(0)	1(2)	1(3)	4(79)	3(39)	3(33)	5(26)	7(58)	4(15)
Betu papy	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(9)	-(0)	3(20)	-(0)	-(0)	-(0)
Abie gran	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)
Thuj plic	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(3)	-(0)	-(0)	-(0)
Tsug hete	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Abie lasi	-(0)	-(0)	1(1)	-(0)	4(1)	-(0)	-(0)	1(0)	1(0)	2(0)	6(1)	3(2)	7(5)	5(1)	2(1)
Tsug mert	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pinu albi	-(0)	1(0)	1(3)	-(0)	2(20)	-(0)	1(1)	1(15)	-(0)	-(0)	-(0)	-(0)	2(0)	3(0)	-(0)
Lari lyal	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
SHRUBS AND SUBSHRUBS															
Alnu sinu	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	1(3)	-(0)
Amel alni	7(1)	6(1)	3(1)	4(1)	1(15)	8(3)	4(1)	-(0)	1(1)	4(1)	10(5)	9(6)	3(1)	5(3)	8(8)
Arte trid	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	3(1)	-(0)	2(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Holo disc	1(1)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Juni comm	-(0)	2(1)	4(7)	1(1)	7(5)	5(1)	9(15)	10(27)	8(5)	3(1)	6(8)	1(1)	3(2)	3(1)	4(2)
Juni hori	-(0)	1(0)	-(0)	-(0)	-(0)	-(0)	1(3)	1(19)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Ledu glan	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)
Menz ferr	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(1)	1(1)	-(0)	-(0)	-(0)
Oplo horr	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pach myrs	-(0)	1(1)	+(2)	-(0)	1(3)	-(0)	-(0)	-(0)	-(0)	-(0)	1(3)	3(1)	-(0)	1(1)	-(0)
Phyl empe	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Phys malv	3(1)	1(1)	+(1)	1(3)	2(2)	-(0)	3(0)	-(0)	-(0)	-(0)	10(66)	-(0)	10(66)	1(1)	-(0)
Prun virg	1(1)	-(0)	1(16)	1(1)	-(0)	1(1)	1(1)	2(2)	2(1)	-(0)	1(1)	1(9)	5(2)	1(2)	-(0)
Purs trid	2(9)	-(0)	-(0)	1(3)	-(0)	1(1)	1(15)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Ribe lacu	-(0)	-(0)	1(1)	-(0)	1(1)	1(15)	1(1)	-(0)	3(1)	8(1)	-(0)	3(1)	2(1)	9(2)	-(0)
Ribe mont	-(0)	-(0)	-(0)	-(0)	1(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Rubu parv	-(0)	-(0)	+(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(3)	3(1)	4(9)	5(0)	4(16)	-(0)
Shep cana	-(0)	5(3)	2(2)	1(2)	-(0)	5(1)	6(2)	5(1)	1(0)	2(1)	4(5)	4(0)	3(1)	4(4)	4(1)
Spir betu	5(5)	7(9)	8(4)	8(8)	8(4)	10(27)	6(8)	9(6)	4(2)	2(2)	9(15)	7(13)	10(3)	5(9)	8(8)
Symp albu	5(2)	6(2)	4(1)	6(2)	7(1)	5(1)	9(1)	4(2)	2(1)	7(1)	10(9)	9(10)	10(5)	8(12)	4(9)
Taxu brev	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	1(1)	-(0)	-(0)	-(0)
Vacc caes	-(0)	1(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	10(9)	1(1)	-(0)	-(0)	10(12)
Vacc glob	-(0)	2(2)	1(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	3(19)	1(8)	2(1)	1(3)	2(1)
Vacc myrt	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	4(3)
Vacc scop	-(0)	3(1)	1(8)	-(0)	-(0)	-(0)	-(0)	1(0)	-(0)	2(1)	3(8)	2(1)	-(0)	1(3)	2(1)
Arct uva-	3(5)	10(37)	3(11)	6(14)	-(0)	3(1)	10(20)	7(1)	1(3)	-(0)	8(5)	2(1)	-(0)	-(0)	8(1)
Berb repe	3(1)	5(1)	7(2)	5(7)	8(1)	6(1)	8(1)	6(5)	5(1)	4(1)	10(8)	8(5)	7(1)	7(6)	8(5)
Linn bore	-(0)	1(1)	1(1)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	4(2)	10(20)	9(12)	2(15)	5(28)	8(8)
FERNS AND FERN ALLIES															
Athy fili	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(2)	-(0)	1(1)	-(0)	1(2)	-(0)
Equi arve	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	10(40)	3(1)	2(5)	-(0)	6(3)	2(1)
Gymn dryo	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)	-(0)
GRAMINOIDS															
Agro scab	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Agro spic	9(11)	4(2)	2(1)	5(1)	1(1)	4(8)	8(1)	4(1)	5(1)	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)
Cala cana	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	2(2)	-(0)
Cala rube	10(28)	10(25)	10(45)	10(42)	5(2)	6(2)	3(1)	3(2)	3(0)	3(1)	9(22)	5(9)	5(1)	5(15)	10(36)
Care geye	7(23)	5(10)	6(13)	8(5)	9(44)	5(2)	1(1)	4(2)	4(1)	-(0)	1(1)	-(0)	7(17)	1(2)	-(0)
Fest idah	8(9)	5(8)	2(1)	3(1)	4(1)	5(4)	6(3)	-(0)	7(2)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Fest scab	3(6)	2(8)	2(1)	1(1)	1(1)	3(2)	5(4)	1(1)	2(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Hesp king	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Luzu hitc	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Oryz aspe	-(0)	-(0)	-(0)	1(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	6(2)	8(2)	-(0)	2(1)	2(1)
Schi purp	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	1(1)	-(0)
FORBS															
Acta rubr	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	3(1)	3(1)	1(1)	5(1)	10(1)	-(0)
Aden bico	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	4(1)	-(0)	-(0)	-(0)
Aral nudi	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(3)	-(0)	7(19)	-(0)	-(0)	-(0)
Arni cord	5(2)	5(4)	9(16)	9(10)	9(23)	6(8)	-(0)	7(4)	9(26)	1(1)	4(1)	1(3)	3(2)	5(6)	8(1)
Arni lati	-(0)	-(0)	1(8)	1(15)	-(0)	1(3)	-(0)	-(0)	1(1)	1(3)	3(8)	3(17)	-(0)	1(1)	2(1)
Bals sagi	9(3)	2(1)	1(1)	4(2)	5(1)	5(6)	8(3)	2(1)	1(1)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)
Clem pseu	-(0)	-(0)	-(0)	-(0)	1(3)	-(0)	5(1)	2(1)	1(1)	-(0)	-(0)	-(0)	2(1)	1(15)	-(0)
Clem tenu	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Clin unif	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	9(3)	6(3)	-(0)	-(0)	-(0)
Copt occi	-(0)	-(0)	+(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Corn cana	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(1)	9(9)	8(5)	-(0)	-(0)	-(0)
Disp trac	-(0)	1(1)	2(1)	1(1)	2(1)	2(1)	1(1)	4(1)	3(1)	-(0)	3(1)	5(1)	10(1)	6(1)	2(1)
Gali bore	1(0)	[illegible]	2(1)	1(1)	5(1)	5(1)	6(1)	5(1)	3(1)	6(1)	8(1)	6(1)	10(1)	3(1)	6(1)
Gali trif	-(0)	-(0)	+(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	9(1)	5(1)	7(3)	10(1)	10(2)	-(0)
Gera rich	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	1(1)	7(1)	-(0)	-(0)	5(1)	6(5)	-(0)
Hier grac	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Osmo chil	-(0)	1(1)	3(1)	1(1)	7(1)	1(1)	1(1)	1(1)	1(1)	6(1)	8(1)	7(2)	8(1)	9(1)	2(1)
Pyro asar	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	6(1)	-(0)	4(0)	-(0)	3(1)	-(0)
Pyro secu	-(0)	[illegible]	3(1)	-(0)	1(1)	3(1)	-(0)	1(1)	1(1)	6(1)	6(1)	5(1)	8(1)	8(2)	2(1)
Pyro unif	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	2(1)	-(0)	-(0)	-(0)	2(0)	-(0)
Sene stre	[illegible]	-(0)	1(1)	[illegible]	-(0)	1(1)	-(0)	1(1)	2(1)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)
Sene tria	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	4(1)	-(0)	-(0)	-(0)	3(1)	-(0)
Smil race	-(0)	1(1)	5(1)	1(1)	6(1)	4(1)	1(1)	2(1)	2(1)	[illegible]	4(1)	3(1)	7(1)	5(1)	-(0)
Smil stel	-(0)	-(0)	1(1)	1(1)	2(1)	1(1)	6(1)	3(1)	1(1)	10(3)	6(1)	7(3)	7(1)	8(1)	2(1)
Stre ampl	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(1)	1(1)	1(1)	-(0)	6(1)	-(0)
Thal occi	[illegible]	[illegible]	5(7)	1(1)	[illegible]	5(1)	1(1)	5(3)	1(1)	7(2)	6(4)	8(1)	10(1)	7(3)	6(1)
Tiar trif	[illegible]	-(0)	[illegible]	[illegible]	-(0)	-(0)	[illegible]	-(0)	[illegible]	-(0)	1(1)	2(1)	-(0)	-(0)	-(0)
Trol laxu	[illegible]	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vale sitc	[illegible]	1(1)	+(1)	[illegible]	1(1)	-(0)	[illegible]	-(0)	1(1)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)
Vera viri	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Viol cana	[illegible]	[illegible]	-(0)	1(17)	-(0)	1(1)	[illegible]	-(0)	-(0)	3(1)	3(1)	4(1)	5(3)	3(10)	-(0)
Viol orbi	[illegible]	-(0)	+(1)	[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	1(1)	8(1)	5(3)	2(1)	1(7)	2(1)
Xero tena	-(0)	1(1)	1(1)	1(1)	1(1)	-(0)	[illegible]	-(0)	[illegible]	-(0)	3(19)	1(1)	-(0)	-(0)	-(0)

*Code to constancy values: + = 0-5%, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%.

[illegible]

[illegible]

	[illegible] SERIES				[illegible] SERIES						THUJA PLICATA SERIES			
	[illegible] h.t.		LIBO h.t.	[illegible] h.t.	XETE [illegible]	[illegible] h.t.			[illegible] h.t.		CLUN h.t.			[illegible] h.t.
	[illegible]	[illegible]				[illegible] phase	ARNU [illegible]	[illegible] phase	[illegible] phase	[illegible] phase	[illegible] phase	ARNU phase	[illegible] phase	
[illegible]	[illegible]	[illegible]	21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	[illegible]	11
TREES														
[illegible]	-(0)	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
Pinu flex	8(8)	-(0)	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]
[illegible]	-(0)	-(0)	[illegible]	[illegible]	[illegible]	5(1)	2(0)	3(0)	6(27)	[illegible]	2(1)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	[illegible]	[illegible]	10(19)	9(41)	10(30)	10(13)	10(14)	10(14)	10(26)	[illegible] 18)	10(17)	9(10)	10(14)	5(5)
[illegible]	-(0)	-(0)	10(39)	8(17)	7(15)	5(11)	[illegible]	8(5)	8(6)	10(7)	[illegible]	[illegible]	7(8)	-(0)
Lari occi	-(0)	-(0)	[illegible]	-(0)	10(16)	3(0)	10(14)	[illegible]	10(19)	[illegible]	[illegible]	7(9)	10(19)	2(2)
[illegible]	-(0)	-(0)	-(0)	-(0)	5([illegible]	[illegible]	3(2)	10(4)	-(0)	[illegible] 0)	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	4(34)	4(26)	-(0)	-(0)	5(15)	-(0)	-(0)	[illegible] 0)	-(0)	2(9)	-(0)	5(9)
[illegible]	[illegible]	4(74)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9(16)	4(18)	9(13)	[illegible]
[illegible]	[illegible]	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	8(5)	[illegible]	2(1)	[illegible]	2(11)	2(15)	-(0)	[illegible]
[illegible]	-(0)	-(0)	-(0)	[illegible]	10(19)	10(54)	10(50)	10(38)	10(38)	[illegible]	[illegible]	7(36)	[illegible]	2(8)
[illegible]	-(0)	-(0)	-(0)	[illegible]	2([illegible]	2(1)	-(0)	3(3)	-(0)	[illegible]	10(62)	[illegible]	10(28)	8(30)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	[illegible] 0)	[illegible]	[illegible]	-(0)	10(40)
[illegible]	2(0)	[illegible]	6(2)	2([illegible]	[illegible]	[illegible]	[illegible]	8(6)	[illegible]	[illegible]	7(10)	6(8)	10(25)	7(5)
[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	6(1)	[illegible]	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	[illegible]
[illegible]														
[illegible]	-(0)	-(0)	2(26)	[illegible] 0)	3([illegible]	-(0)	-(0)	-(0)	4(1)	[illegible]	1(2)	-(0)	3(19)	-(0)
[illegible]	-(0)	[illegible]	[illegible]	3(1)	7([illegible]	[illegible]	[illegible]	10(5)	10(2)	7(1)	[illegible]	6(4)	3(1)	2(0)
[illegible]	-(0)	[illegible]	-(0)	[illegible]	-(0)	[illegible]	[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
Holo disc	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	3(1)	[illegible]	[illegible]	[illegible] 0)	-(0)	1(1)	-(0)	-(0)
[illegible]	[illegible]	[illegible]	[illegible]	6([illegible]	-(0)	2(1)	-(0)	[illegible]	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	2(1)	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible] 0)	[illegible]	-(0)	-(0)	-(0)
Menz ferr	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	[illegible]	[illegible]	1(3)	10(8)	[illegible]
[illegible]	-(0)	-(0)	-(0)	[illegible] 0)	[illegible]	[illegible]	-(0)	-(0)	[illegible]	[illegible] 0)	-(0)	2(1)	-(0)	10(28)
[illegible]	[illegible]	-(0)	[illegible]	-(0)	[illegible]	[illegible]	-(0)	8(1)	[illegible]	[illegible]	5(1)	2(9)	7(12)	[illegible]
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	[illegible]	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	2(15)	-(0)	-(0)	8(1)	[illegible] 0)	-(0)	1(1)	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	4(1)	-(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)
Purs trid	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]
[illegible]	2(1)	6(0)	3(1)	4(1)	-(0)	[illegible]	2(1)	-(0)	2(1)	[illegible] 0)	4(0)	4(1)	[illegible]	7(1)
Ribe mont	4(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible] 0)	-(0)	[illegible]	-(0)	[illegible]
Rubu parv	-(0)	-(0)	4(0)	-(0)	5(0)	[illegible]	8(3)	3(1)	6(1)	[illegible]	7(1)	8(4)	6(1)	[illegible]
Shep cana	10(1)	-(0)	6(10)	5(1)	2(1)	2(1)	-(0)	3(1)	[illegible]	[illegible]	2(1)	-(0)	1(3)	-(0)
Spir betu	2(1)	-(0)	[illegible]	[illegible] 6)	8([illegible]	7(8)	5(1)	[illegible]	10(2)	[illegible] 1)	5([illegible]	2(9)	3(3)	[illegible]
[illegible]	-(0)	-(0)	6(4)	[illegible] 8)	-(0)	[illegible]	8(11)	3(15)	[illegible]	[illegible]	3(1)	8(12)	-(0)	[illegible]
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	[illegible] 0)	4([illegible]	3(6)	7(26)	5(4)
Vacc caes	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	2(1)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]
[illegible]	-(0)	-(0)	7(13)	2([illegible]	10(22)	7(2)	2(1)	10(21)	[illegible]	[illegible]	[illegible]	3(6)	9(11)	6(1)
[illegible]	-(0)	-(0)	-(0)	[illegible] 0)	[illegible]	-(0)	-(0)	-(0)	2(1)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	4(0)	5(18)	[illegible]	2(1)	-(0)	-(0)	3(0)	[illegible]	[illegible] 1)	3(1)	-(0)	[illegible]	1(1)
[illegible]	[illegible]	-(0)	6(2)	2(1)	[illegible] 1)	2(1)	-(0)	3(0)	4(1)	[illegible] 1)	-(0)	-(0)	-(0)	-(0)
Berb repe	[illegible]	-(0)	6(1)	7(4)	8([illegible]	8(3)	7(5)	8(1)	6(1)	7(1)	7(2)	[illegible]	-(0)	-(0)
Linn bore	-(0)	-(0)	10(19)	-(0)	-(0)	[illegible]	8(8)	[illegible]	[illegible]	10(2)	9(4)	7(11)	6(9)	2(1)
FERNS AND FERN ALLIES														
[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	2(1)	2(15)	-(0)	-(0)	[illegible]	1([illegible]	7(3)	-(0)	10(22)
Equi arve	-(0)	[illegible]	1(1)	1([illegible]	[illegible] 0)	-(0)	[illegible]	-(0)	-(0)	[illegible]	-(0)	[illegible]	-(0)	4(1)
Gymn dryo	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	2(0)	6(1)	-(0)	10(28)
GRAMINOIDS														
Agro scab	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	-(0)	-(0)
Agro spic	-(0)	[illegible]	[illegible]	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
Cala cana	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	[illegible]	[illegible]	7(23)	10(14)	7(14)	3(8)	[illegible]	10(14)	[illegible] 3)	3(1)	[illegible]	[illegible]	-(0)
Care geye	[illegible]	-(0)	3(7)	[illegible]	2(0)	2(1)	2(3)	[illegible]	4(1)	[illegible] 0)	1(1)	-(0)	1(1)	-(0)
Fest idah	8(1)	10(1)	-(0)	1(1)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	[illegible]	8(1)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
Hesp king	4(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
Luzu hitc	-(0)	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	1(14)	[illegible] 1)	-(0)	2(0)	3(2)	-(0)	-(0)	[illegible] 0)	[illegible] 1)	1(1)	-(0)	-(0)
Schi purp	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	-(0)	-(0)
[illegible]														
Acta rubr	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	[illegible]	3(1)	[illegible]	-(0)	8(1)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	7(0)	7(6)	8(5)	[illegible]	[illegible]	3(1)	[illegible]	1(1)	8(5)
[illegible]	[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	8(17)	-(0)	-(0)	[illegible]	-(0)	7(14)	-(0)	6(4)
[illegible]	4(2)	4(1)	9(4)	7(13)	-(0)	3(8)	2(3)	-(0)	4(2)	[illegible] 1)	-(0)	-(0)	1(1)	-(0)
[illegible]	-(0)	[illegible]	2(14)	1(3)	[illegible]	7(8)	7(11)	8(18)	4(15)	[illegible] 0)	4(12)	2(20)	[illegible]	1(1)
Bals sagi	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	[illegible]	-(0)	-(0)
[illegible]	4(1)	[illegible]	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	-(0)	-(0)
[illegible]	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	[illegible]	-(0)
Clin unif	-(0)	[illegible]	[illegible]	-(0)	-(0)	[illegible]	8(2)	10(5)	2(0)	[illegible] 0)	[illegible]	9(10)	9(3)	9(10)
[illegible]	-(0)	-(0)	-(0)	-(0)	[illegible]	3(8)	-(0)	3(0)	-(0)	[illegible]	2(11)	3(34)	3(2)	[illegible]
[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-([illegible]	[illegible]	4(1)	-(0)	1(1)
Disp trac	-(0)	-(0)	[illegible]	[illegible]	2([illegible]	5(1)	-(0)	[illegible]	[illegible]	-([illegible]	2(1)	[illegible]	-(0)	[illegible]
Gali bore	[illegible]	[illegible]	5(1)	7([illegible]	-(0)	-(0)	2(1)	[illegible]	-(0)	[illegible]	-([illegible]	-(0)	-(0)	-(0)
Gali trif	-(0)	[illegible]	[illegible]	2([illegible]	-(0)	10(3)	7(1)	[illegible]	4(1)	[illegible]	5(1)	10(2)	-(0)	10(3)
[illegible]	-(0)	-(0)	2(0)	5(2)	[illegible]	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]
[illegible]	[illegible]	6(1)	5(1)	10(1)	2([illegible]	[illegible]	10(1)	8(1)	4(1)	3(1)	3(0)	10(4)	1(1)	10(1)
[illegible]	[illegible]	-(0)	[illegible]	[illegible] 1)	2([illegible]	2(1)	3(2)	3(1)	4(1)	[illegible] 1)	5(1)	4(1)	[illegible] 1)	3(1)
[illegible]	10(0)	8(1)	[illegible]	[illegible]	[illegible]	[illegible]	5(1)	3(1)	8(1)	7(1)	9(1)	6(1)	9(2)	3(1)
[illegible]	-(0)	4(1)	[illegible]	[illegible]	-(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	1(1)	-(0)	-(0)	[illegible]
[illegible]	8(1)	10(1)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)	[illegible] 0)	[illegible] 1)	4(1)	-(0)	1(1)
[illegible]	-(0)	-(0)	3(1)	[illegible] 1)	-(0)	3(1)	[illegible]	3(1)	4(1)	-([illegible]	5([illegible]	[illegible]	[illegible]	3(1)
[illegible]	-(0)	-(0)	2(1)	[illegible] 1)	2(1)	8(4)	[illegible]	5(8)	8(1)	7(1)	5([illegible]	[illegible]	1(1)	10(1)
[illegible]	-(0)	-(0)	+(0)	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)	[illegible] 0)	[illegible] 1)	[illegible]	-(0)	5(1)
[illegible]	-(0)	[illegible]	[illegible]	[illegible]	[illegible] 1)	[illegible]	[illegible]	8(6)	[illegible]	[illegible] 0)	3(1)	3(1)	4(1)	7(1)
Tiar trif	-(0)	-(0)	-(0)	-(0)	[illegible]	2(3)	3(3)	-(0)	-(0)	[illegible] 0)	4(0)	[illegible]	1 [illegible]	10(18)
[illegible]	-(0)	-(0)	-(0)	-(0)	[illegible] 0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	[illegible] 0)	1([illegible]	-(0)	-(0)	6(0)
[illegible]	[illegible]	-(0)	[illegible]	[illegible]	-(0)	2(1)	[illegible]	[illegible]	-(0)	[illegible]	-(0)	[illegible]	[illegible]	-(0)
Viol orbi	-(0)	[illegible]	+(1)	[illegible]	[illegible] 1)	7(1)	7(1)	8(1)	4(3)	[illegible]	7(1)	9(2)	[illegible]	8(2)
[illegible]	-(0)	-(0)	[illegible]	-(0)	10(13)	3(1)	-(0)	10(24)	-(0)	[illegible]	4(2)	-(0)	[illegible]	-(0)

* [illegible] = [illegible] 8%, [illegible]

APPENDIX C (con.)

[illegible]

onstancy* and average canopy coverage percent (the latter in parentheses) of important [illegible]

	TSUGA HETEROPHYLLA SERIES		ABIES LASIOCARPA SERIES										
	CLUN h.t.		OPHO h.t.	CLUN h.t.					GATR h.t.	VACA h.t.	CACA h.t.		
	CLUN phase	ARNU phase		CLUN phase	ARNU phase	VACA phase	XETE phase	MEFE phase			CACA phase	GATR phase	VACA phase
No. of stands	27	11	4	32	15	16	21	22	14	10	25	8	[illegible]
TREES													
Juni scop	(0)	(0)	(0)	-(0)	-(0)	(0)	-(0)	(0)	-(0)	1(1)		-(0)	([illegible]
Pinu flex	-(0)	(0)	(0)	-(0)	(0)	(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	([illegible]
Pinu pond	+(15)	-(0)	-(0)	2(5)	1(1)	4(2)	-(0)	(0)	+(1)	(0)	-(0)	[illegible]	[illegible]
Frax penn	(0)	(0)	(0)	-(0)	(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	[illegible]
Pseu menz	7(6)	5(2)	8(0)	8(24)	7(10)	9(15)	9(24)	8(24)	7(16)	6(3)	+(0)	-(0)	3([illegible]
Pinu cont	4(5)	1(3)	(0)	6(18)	4(6)	9(25)	6(13)	7(9)	8(15)	10(47)	7(21)	[illegible]	10(45)
Lari occi	8(13)	6(9)	8(6)	8(2)	8(16)	7(11)	8(11)	6(6)	1(39)	1(15)	-(0)	-(0)	-([illegible]
Pinu mont	8(8)	6(7)	7(2)	2(5)	5(1)	5(1)	3(12)	1(8)	-(0)	-(0)	-(0)	-(0)	[illegible]
Pice glau	4(3)	2(3)	3(15)	[illegible]	3(11)	5(9)	-(0)	(0)	1(52)	3(2)	+(3)	2(37)	[illegible]
Pice enge	3(7)	3(25)	8(31)	8(2)	7(29)	5(5)	10(16)	[illegible]	8(39)	5(1)	10(39)	8(32)	10(7)
Betu papy	4(3)	5(2)	(0)	+(3)	4(12)	(0)	-(0)	-(0)	-(0)	-(0)	[illegible]	-(0)	-(0)
Abie gran	3(11)	4(38)	-(0)	3(8)	2(6)	3(1)	2(2)	2(36)	-(0)	-(0)	(0)	(0)	(0)
Thuj plic	9(23)	8(29)	-(0)	+(3)	(0)	(0)	+(0)	2(1)	(0)	-(0)	-(0)	-(0)	-([illegible]
Tsug hete	10(24)	10(43)	3(3)	1(0)	2(2)	(0)	1(10)	+(0)	(0)	(0)	-(0)	-(0)	1(0)
Abie lasi	4(8)	3(18)	10(26)	10(32)	10(30)	10(12)	10(30)	10(31)	10(33)	10(4)	10(17)	10(24)	10(12)
Tsug mert	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	1(18)	+(37)	-(0)	[illegible]	(0)	(0)	(0)
Pinu albi	(0)	(0)	(0)	1(6)	-(0)	1(1)	1(1)	1(8)	1(0)	5(1)	6(3)	-(0)	1(1)
Lari lyal	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	[illegible]	-(0)	[illegible]	(0)	[illegible]	(0)
SHRUBS AND SUBSHRUBS													
Alnu sinu	+(3)	1(3)	-(0)	3(6)	2(13)	1([illegible]	4(6)	1(5)	1(25)	-(0)	-(0)	-(0)	1(1)
Amel alni	5(1)	7(1)	(0)	6(2)	7(1)	8(4)	7(3)	3(2)	4(1)	1(1)	(0)	(0)	(0)
Arte trid	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)
Holo disc	+(1)	1(3)	-(0)	-(0)	1(1)	(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Juni comm	1(2)	-(0)	-(0)	1(8)	1(8)	6(7)	1(1)	(0)	1(0)	7(2)	2(1)	2(1)	3(2)
Juni hori	-(0)	(0)	-(0)	-(0)	-(0)	(0)	-(0)	(0)	(0)	-(0)	-(0)	[illegible]	-(0)
Ledu glan	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	1(1)	7(17)	-(0)	6(8)
Menz ferr	4(1)	2(2)	5(8)	4(2)	4(1)	3(0)	5(2)	10(29)	2(1)	1(1)	1(31)	2(1)	-(0)
Oplo horr	+(1)	3(1)	10(38)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	(0)	-(0)
Pach myrs	8(3)	6(3)	5(1)	6(9)	7(5)	6(10)	8(4)	5(6)	1(3)	1(1)	-(0)	-(0)	-(0)
Phyl empe	(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	3(3)	-(0)	(0)
Phys malv	-(0)	(0)	-(0)	1(6)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)
Prun virg	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)
Purs trid	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Ribe lacu	1(1)	3(5)	5(2)	4(1)	4(2)	(0)	3(1)	5(3)	9(1)	-(0)	3(1)	10(1)	3(2)
Ribe mont	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Rubu parv	3(0)	7(1)	8(1)	7(5)	10(9)	6(1)	7(4)	8(2)	6(6)	-(0)	+(1)	-(0)	-(0)
Shep cana	1(1)	1(1)	-(0)	2(1)	1(1)	8(3)	2(4)	+(1)	1(5)	4(0)	+(1)	-(0)	4(1)
Spir betu	5(5)	5(7)	3(1)	6(3)	9(6)	10(9)	8(5)	5(3)	5(5)	5(2)	2(1)	2(1)	3(1)
Symp albu	1(1)	5(1)	5(8)	4(5)	6(5)	6(4)	1(1)	+(1)	4(5)	-(0)	-(0)	-(0)	-(0)
Taxu brev	4(18)	5(8)	10(29)	2(1)	6(7)	1(1)	2(2)	3(15)	-(0)	-(0)	-(0)	-(0)	-(0)
Vacc caes	+(1)	-(0)	-(0)	1(0)	1(1)	9(17)	1(1)	-(0)	-(0)	10(21)	-(0)	-(0)	9(20)
Vacc glob	9(13)	7(3)	8(1)	9(12)	8(14)	8(18)	10(27)	10(22)	6(8)	4(4)	3(4)	4(2)	-(0)
Vacc myrt	-(0)	1(1)	-(0)	1(5)	1(0)	1(3)	+(3)	-(0)	1(1)	2(8)	+(1)	(0)	3(7)
Vacc scop	3(9)	3(1)	5(1)	2(10)	1(1)	2(9)	3(9)	2(2)	4(8)	8(20)	9(28)	10(2)	4(30)
Arct uva-	2(5)	-(0)	(0)	1(1)	1(1)	10(11)	+(1)	-(0)	+(1)	6(1)	-(0)	-(0)	3(14)
Berb repe	4(1)	4(1)	-(0)	6(3)	6(3)	10(4)	3(3)	2(1)	5(1)	3(1)	+(1)	-(0)	1(1)
Linn bore	8(18)	7(4)	3(15)	6(17)	8(15)	10(31)	4(10)	5(20)	4(10)	4(18)	-(0)	1(9)	6(11)
FERNS AND FERN ALLIES													
Athy fili	+(0)	5(1)	10(17)	+(0)	3(12)	-(0)	+(1)	+(1)	1(0)	-(0)	-(0)	2(1)	-(0)
Equi arve	+(1)	1(1)	-(0)	1(1)	1(1)	-(0)	-(0)	(0)	2(3)	-(0)	2(1)	6(1)	1(1)
Gymn dryo	2(0)	6(2)	10(12)	-(1)	5(14)	-(0)	+(0)	2(0)	-(0)	-(0)	-(0)	-(0)	(1)
GRAMINOIDS													
Agro scab	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	1(1)	-(0)	-(0)	-(0)
Agro spic	-(0)	(0)	(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Cala cana	-(0)	-(0)	-(0)	-(0)	1(0)	(0)	-(0)	+(15)	1(2)	1(1)	7(21)	10(17)	10(25)
Cala rube	1(14)	-(0)	-(0)	6(8)	2(1)	9(8)	3(4)	1(1)	6(7)	9(37)	1(1)	4(2)	6(17)
Care geye	+(1)	(0)	-(0)	3(1)	1(0)	1(1)	3(1)	-(0)	4(11)	4(1)	1(5)	2(3)	3(8)
Fest idah	-(0)	-(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	1(1)	-(0)	(0)	1(1)
Fest scab	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	(0)	1(1)
Hesp king	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)
Luzu hitc	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	2(5)	(0)	-(0)
Oryz aspe	1(1)	1(0)	-(0)	+(1)	3(1)	3(1)	-(0)	(0)	1(2)	-(0)	-(0)	-(0)	-(0)
Schi purp	(0)	(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)
FORBS													
Acta rubr	1(1)	3(1)	10(1)	2(1)	1(1)	-(0)	1(1)	1(1)	7(2)	-(0)	-(0)	4(2)	(0)
Aden bico	2(0)	6(5)	5(3)	2(1)	6(1)	1(3)	2(1)	+(1)	(0)	-(0)	-(0)	-(0)	(0)
Aral nudi	3(1)	9(5)	5(9)	-(0)	7(17)	1(1)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(1)
Arni cord	-(0)	-(0)	-(0)	2(9)	-(0)	3(1)	1(1)	-(0)	5(10)	8(2)	3(4)	6(1)	6(8)
Arni lati	1(14)	2(26)	8(7)	9(21)	8(23)	5(5)	8(17)	9(33)	5(5)	1(3)	7(9)	4(9)	4(2)
Bals sagi	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Clem pseu	-(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	(0)	-(0)	-(0)	(0)	(0)	-(0)
Clem tenu	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	1(1)	(0)	-(0)	-(0)	(0)
Clin unif	9(10)	10(9)	10(6)	10(5)	9(9)	10(3)	10(5)	10(7)	[illegible]	(0)	-(0)	-(0)	1(0)
Copt occi	1(13)	1(3)	(0)	1(17)	2(15)	-(0)	-(0)	4(11)	1(19)	-(0)	-(0)	(0)	(0)
Corn cana	3(1)	5(1)	3(1)	2(4)	7(5)	5(4)	1(8)	1(3)	1(19)	-(0)	+(1)	-(0)	4(1)
Disp trac	-(0)	(0)	-(0)	3(1)	2(1)	-(0)	+(1)	1(1)	4(1)	-(0)	(0)	-(0)	-(0)
Gali bore	-(0)	-(0)	(0)	2(0)	-(0)	4(1)	1(1)	-(0)	4(1)	1(1)	+(1)	(0)	1(1)
Gali trif	3(1)	6(1)	8(1)	4(1)	8(1)	2(2)	4(1)	6(1)	10(1)	-(0)	-(0)	10(3)	1(0)
Gera rich	-(0)	-(0)	-(0)	+(1)	-(0)	(0)	-(0)	(0)	1(1)	1(0)	1(1)	4(1)	-(0)
Hier grac	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	(0)	(0)	-(0)	3(1)	2(1)	1(1)
Osmo chil	4(1)	6(1)	8(1)	7(2)	9(1)	8(1)	7(1)	6(2)	9(2)	-(0)	5(1)	8(1)	3(1)
Pyro asar	7(1)	5(0)	(0)	1(1)	6(1)	2(1)	6(1)	5(1)	3(1)	1(0)	3(1)	8(1)	4(1)
Pyro secu	10(1)	7(1)	5(1)	8(1)	7(1)	4(1)	9(1)	9(2)	10(1)	4(0)	5(1)	8(2)	3(2)
Pyro unif	1(1)	2(1)	(0)	1(0)	1(1)	(0)	-(0)	1(1)	3(1)	-(0)	(0)	8(1)	[illegible]
Sene stre	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)
Sene tria	-(0)	-(0)	(0)	2(1)	2(2)	-(0)	1(1)	2(5)	4(1)	-(0)	3(10)	6(5)	1(1)
Smil race	2(1)	2(1)	3(1)	3(1)	3(1)	4(1)	1(1)	1(1)	4(0)	1(1)	-(0)	-(0)	-(0)
Smil stel	6(1)	9(1)	10(5)	3(2)	8(1)	5(1)	4(1)	3(7)	5(1)	-(0)	-(0)	2(1)	3(1)
Stre ampl	+(0)	2(0)	5(1)	2(1)	3(1)	-(0)	-(0)	2(1)	5(1)	-(0)	4(0)	10(1)	3(2)
Thal occi	1(1)	3(1)	10(1)	8(5)	9(1)	3(1)	10(2)	7(4)	10(6)	2(1)	4(10)	10(2)	3(2)
Tiar trif	6(1)	10(6)	10(12)	3(4)	8(4)	1(1)	6(4)	5(10)	1(1)	-(0)	1(1)	-(0)	1(1)
Trol laxu	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	(0)	1(1)	-(0)	7(3)	-(0)	1(3)
Vale sitc	-(0)	-(0)	-(0)	1(2)	(0)	-(0)	-(0)	1(1)	2(1)	-(0)	6(1)	2(1)	3(3)
Vera viri	-(0)	-(0)	8(1)	-(1)	3(1)	(0)	2(1)	1(1)	2(1)	-(0)	5(4)	2(3)	1(3)
Viol cana	-(0)	-(0)	8(2)	(0)	1(1)	-(0)	-(0)	1(1)	1(1)	-(0)	+(3)	-(0)	-(0)
Viol orbi	9(1)	9(2)	10(2)	8(2)	7(2)	8(2)	9(2)	9(3)	6(1)	1(1)	5(2)	4(1)	4(1)
Xero tena	5(10)	3(0)	3(1)	6(2)	4(2)	6(44)	10(27)	9(9)	2(6)	1(63)	3(7)	2(1)	3([illegible]

*Code to constancy values: + = 0-5%, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%

(con.)

[illegible]

See instructions for use on page 1[illegible]

[illegible] of important plants in Montana forest habitat types and phases

	ABIES LASIOCARPA SERIES (con.)														
	LIBO h.t.			MEFE h.t.	TSME MEFE h.t.	XETE h.t.		TSME XETE h.t.	VAGL h.t.	VASC h.t.			ALSI h.t.	CARU h.t.	CLPS h.t.
	LIBO phase	XETE phase	VASC phase			VAGL phase	VASC phase			CARU phase	VASC phase	THOC phase			
No. of stands	[illegible]	13	[illegible]	64	[illegible]	[illegible]	21	9	21	10	17	10	6	8	15
TREES															
Juni scop	1(1)	(0)	-(0)	-(0)	(0)	-(0)	[illegible]	[illegible]	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)
Popu trem	[illegible]	[illegible]	1(1)	-(0)	(0)	[illegible]	[illegible]	[illegible]	+(3)	-(0)	[illegible]	1(0)	-(0)	-(0)	10(17)
Pinu pond	3(11)	+(3)	-(0)	-(0)	(0)	[illegible]	-(0)	[illegible]	-(0)	[illegible]	[illegible]	-(0)	-(0)	-(0)	1(0)
Frax penn	[illegible]	(0)	-(0)	-(0)	(0)	[illegible]	[illegible]	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pseu menz	[illegible]	[illegible]	[illegible]	(16)	(3)	9(22)	2(4)	3(10)	8(18)	8(26)	1(2)	1(0)	3(33)	10(28)	9(35)
Pinu cont	[illegible]	[illegible]	10(44)	8(17)	6(5)	9(18)	[illegible]	(11)	10(30)	10(45)	9(47)	9(26)	10(29)	9(45)	3(5)
Lari occi	(33)	+(16)	[illegible]	3(9)	(7)	4(9)	[illegible]	4(12)	+(37)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pinu mont	(0)	[illegible]	-(0)	+(3)	3(3)	3(7)	[illegible]	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pice glau	[illegible]	[illegible]	1(13)	-(0)	(0)	-(0)	-(0)	(0)	1(15)	2(3)	[illegible]	-(0)	(0)	-(0)	5(26)
Pice engl	[illegible]	[illegible]	9(9)	9(18)	9(5)	7(10)	8(5)	7(3)	6(12)	8(6)	4(5)	10(33)	10(24)	8(12)	4(30)
Betu papy	[illegible]	[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	(0)	-(0)	[illegible]	(0)	-(0)	-(0)	-(0)	-(0)
Abie gran	[illegible]	2(2)	-(0)	+(3)	(0)	2(1)	-(0)	2(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)
Thuj plic	[illegible]	[illegible]	-(0)	+(1)	[illegible]	+(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)
Tsug hete	[illegible]	[illegible]	-(0)	+(0)	[illegible]	[illegible]	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)
Abie lasi	[illegible]	[illegible]	10(14)	10(30)	10(21)	10(26)	10(24)	10(13)	-(0)	10(14)	10(18)	10(32)	10(28)	10(22)	10(22)
Tsug mert	[illegible]	[illegible]	-(0)	+(3)	10(28)	1(3)	1(2)	10(25)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pinu albi	2(1)	1(0)	4(1)	4(5)	4(3)	4(7)	5([illegible])	7(2)	6(7)	5(1)	8(2)	6(1)	7(4)	4(0)	3(10)
Lari lyal	[illegible]	[illegible]	-(0)	+(37)	[illegible]	1(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
SHRUBS AND SUBSHRUBS															
Alnu sinu	4(4)	2(2)	1(0)	3(13)	(0)	3(3)	+(1)	2(2)	1(0)	-(0)	1(3)	-(0)	10(36)	-(0)	-(0)
Amel alni	(1)	+(3)	1(1)	1(0)	(0)	7(1)	1(1)	(0)	1(1)	-(0)	-(0)	-(0)	-(0)	3(1)	1(0)
Arte trid	[illegible]	(0)	-(0)	-(0)	(0)	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Holo disc	[illegible]	[illegible]	-(0)	-(0)	(0)	[illegible]	-(0)	[illegible]	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)
Juni comm	3(1)	2(1)	6(2)	+(1)	(0)	+(1)	1(1)	-(0)	5(1)	5(8)	2(1)	3(1)	2(1)	6(1)	7(3)
Juni hori	(0)	[illegible]	-(0)	-(0)	(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)
Ledu glan	[illegible]	(0)	1(1)	1(4)	(0)	-(0)	1(2)	(0)	+(1)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)
Menz ferr	4(1)	7(2)	1(2)	10(45)	10(41)	3(1)	1(2)	(3)	(0)	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)
Oplo horr	[illegible]	[illegible]	-(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pach myrs	3(2)	6(10)	-(0)	1(8)	1(1)	4(5)	-(0)	1(3)	1(8)	-(0)	1(1)	-(0)	-(0)	1(1)	1(3)
Phyl empe	(0)	(0)	-(0)	1(0)	(0)	(0)	-(0)	1(85)	-(0)	-(0)	1(1)	-(0)	2(1)	-(0)	-(0)
Phys malv	2(4)	[illegible]	-(0)	+(9)	(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	1(0)
Prun virg	[illegible]	(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Purs trid	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Ribe lacu	5(1)	1(1)	2(0)	4(2)	-(0)	1(1)	+(1)	1(3)	4(1)	3(1)	1(1)	1(1)	5(1)	4(1)	1(2)
Ribe mont	(0)	(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(4)
Rubu parv	6(1)	6(1)	-(0)	2(1)	(0)	1(1)	-(0)	1(1)	3(1)	1(1)	-(0)	-(0)	2(3)	-(0)	1(1)
Shep cana	6(2)	3(1)	5(8)	1(5)	(0)	1(5)	+(1)	(0)	4(5)	2(8)	-(0)	-(0)	-(0)	4(13)	5(1)
Spir betu	9(4)	7(7)	8(1)	1(1)	-(0)	6(1)	5(1)	1(3)	10(2)	8(4)	4(1)	3(1)	3(1)	5(12)	5(6)
Symp albu	3(1)	2(2)	1(1)	+(1)	-(0)	+(1)	+(1)	(0)	1(2)	3(1)	-(0)	-(0)	-(0)	5(8)	3(2)
Taxu brev	(5)	2(19)	-(0)	-(0)	(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)
Vacc caes	1(1)	(0)	1(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vacc glob	7(6)	10(23)	6(9)	8(13)	9(25)	10(34)	4(1)	10(27)	10(37)	6(2)	1(8)	3(6)	7(11)	5(2)	-(0)
Vacc myrt	1(1)	1(1)	1(1)	1(22)	-(0)	1(8)	2(32)	(0)	1(9)	-(0)	-(0)	2(8)	3(9)	-(0)	-(0)
Vacc scop	5(2)	5(24)	10(43)	6(21)	9(15)	7(12)	9(58)	9(28)	8(33)	10(52)	10(58)	9(45)	5(1)	4(1)	-(0)
Arct uva	3(8)	5(3)	4(1)	+(18)	(0)	1(8)	+(1)	-(0)	+(1)	4(0)	1(1)	-(0)	-(0)	3(2)	1(1)
Berb repe	5(2)	7(3)	5(1)	1(1)	(0)	3(1)	+(1)	(0)	5(1)	7(1)	1(0)	1(1)	2(1)	6(1)	7(1)
Linn bore	10(21)	10(10)	10(19)	2(11)	(0)	1([illegible])	-(0)	-(0)	+(1)	1(1)	-(0)	1(1)	2(0)	3(0)	-(0)
FERNS AND FERN ALLIES															
Athy fili	(0)	(0)	(0)	+(1)	-(0)	+(1)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Equi arve	1(1)	(0)	-(0)	-(0)	(0)	(1)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)
Gymn dryo	(0)	-(0)	-(0)	+(1)	(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
GRAMINOIDS															
Agro scab	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)
Agro spic	1(1)	-(0)	(0)	-(0)	(0)	-(0)	-(0)	-(0)	(0)	-(0)	1(0)	-(0)	-(0)	-(0)	2(1)
Cala cana	(0)	(0)	1(0)	+(8)	(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	3(1)	-(0)	-(0)	-(0)
Cala rube	9(6)	6(8)	10(13)	2(3)	(0)	6(7)	4(2)	2(8)	5(7)	9(13)	5(1)	5(4)	5(1)	10(32)	1(1)
Care geye	2(2)	3(1)	4(3)	+(1)	(0)	5(2)	7(5)	1(1)	8(6)	8(14)	7(11)	5(4)	3(8)	8(15)	5(3)
Fest idah	-(0)	(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	1(1)	4(1)
Fest scab	(0)	(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(1)
Hesp king	(0)	(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)
Luzu hitc	(0)	(0)	-(0)	+(1)	-(0)	+(1)	+(1)	-(0)	-(0)	-(0)	1(0)	-(0)	-(0)	-(0)	-(0)
Oryz aspe	-(0)	(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)
Schi purp	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
FORBS															
Acta rubr	2(1)	(0)	1(1)	+(1)	-(0)	-(0)	-(0)	-(0)	+(1)	(0)	-(0)	(0)	-(0)	1(1)	1(1)
Aden bico	-(0)	1(1)	-(0)	+(1)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Aral nudi	(0)	[illegible]	-(0)	[illegible]	(0)	-(0)	[illegible]	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Arni cord	6(6)	1(1)	(4)	+(1)	(0)	2(2)	2(1)	-(0)	8(5)	9(5)	4(1)	8(5)	5(13)	9(15)	10(7)
Arni lati	7(24)	8(12)	4(11)	9(21)	5(12)	6(10)	7(6)	4(5)	4(12)	2(19)	5(4)	6(11)	3(20)	1(63)	2(3)
Bals sagi	(0)	(0)	-(0)	[illegible]	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Clem pseu	1(1)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	7(4)
Clem tenu	[illegible]	(0)	-(0)	[illegible]	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(2)
Clin unif	1(0)	2(0)	-(0)	-(0)	(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Copt occi	[illegible]	1(1)	-(0)	+(3)	(0)	1(1)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Corn cana	-(0)	(0)	1(3)	+(1)	-(0)	-(0)	+(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Disp trac	3(0)	+(1)	-(0)	+(1)	(0)	-(0)	-(0)	-(0)	2(0)	1(1)	-(0)	-(0)	-(0)	3(1)	3(1)
Gali bore	4(1)	(0)	2(1)	-(0)	(0)	-(0)	-(0)	(0)	2(1)	5(1)	1(1)	-(0)	-(0)	5(1)	10(2)
Gali trif	3(0)	2(1)	1(1)	2(1)	(0)	+(1)	-(0)	-(0)	1(1)	1(0)	-(0)	-(0)	2(1)	1(1)	-(0)
Gera rich	2(1)	(0)	1(1)	-(0)	(0)	-(0)	(0)	-(0)	+(3)	1(1)	-(0)	2(1)	-(0)	1(0)	-(0)
Hier grac	(0)	(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	4(0)	4(1)	-(0)	-(0)	-(0)
Osmo chil	7(1)	4(0)	2(1)	2(1)	-(0)	3(1)	1(1)	-(0)	7(1)	5(1)	1(1)	8(1)	3(1)	9(1)	7(1)
Pyro asar	3(0)	3(1)	1(1)	5(1)	4(2)	2(0)	-(0)	3(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pyro secu	10(2)	7(1)	9(0)	9(1)	7(2)	7(1)	5(2)	7(2)	8(2)	7(2)	2(0)	7(1)	10(1)	9(1)	7(1)
Pyro unif	1(1)	(0)	-(0)	+(1)	(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)
Sene stre	1(1)	(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	3(1)	5(1)
Sene tria	(0)	(0)	-(0)	1(2)	-(0)	+(3)	-(0)	-(0)	-(0)	-(0)	1(1)	1(1)	2(0)	-(0)	-(0)
Smil race	(1)	2(1)	2(1)	1(1)	-(0)	1(1)	-(0)	(0)	2(1)	2(1)	1(1)	-(0)	-(0)	4(1)	2(1)
Smil stel	2(1)	(0)	1(1)	+(2)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	4(2)	3(1)
Stre ampl	-(0)	-(0)	-(0)	1(1)	(0)	-(0)	-(0)	(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Thal occi	8(3)	4(1)	4(8)	4(3)	-(0)	5(3)	1(1)	-(0)	8(1)	4(8)	1(1)	9(6)	5(1)	8(16)	6(4)
Tiar trif	-(0)	1(1)	-(0)	2(2)	(0)	1(2)	-(0)	1(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Trol laxu	(0)	[illegible]	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vale sitc	1(1)	1(1)	1(1)	1(1)	(0)	2(2)	3(1)	1(1)	2(1)	2(2)	1(0)	4(1)	-(0)	3(1)	-(0)
Vera viri	1(1)	-(0)	-(0)	1(1)	(0)	+(1)	+(0)	-(0)	1(1)	-(0)	1(1)	-(0)	2(3)	1(1)	-(0)
Viol cana	1(1)	-(0)	[illegible]	+(1)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(0)	1(3)
Viol orbi	7(2)	8(1)	4(1)	5(1)	2(1)	7(1)	4(1)	-(0)	+(1)	-(0)	-(0)	4(1)	2(1)	1(15)	-(0)
Xero tena	4(2)	[illegible]	1(1)	8(17)	10(31)	10(46)	10(20)	10(41)	1(3)	-(0)	2(1)	-(0)	2(3)	1(3)	1(1)

*Code to constancy values: + = 0-5%, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%

(con.)

APPENDIX C-1 (con.)

(See instructions for use on page 126)

Constancy* and average canopy coverage percent (the latter in parentheses) of important plants in Montana forest habitat types and phases

	ABIES LASIOCARPA SERIES (con.)										PINUS CONTORTA SERIES				
	ARCO h.t.	CAGE h.t.		RIMO h.t.	ABLA-PIAL/VASC h.t.	LUHI h.t.		PIAL-ABLA h.t.	LALY-ABLA h.t.	PIAL h.t.	PUTR h.t.	VACA c.t.	LIBO c.t.	VASC c.t.	CARU c.t.
		CAGE phase	PSME phase			VASC phase	MEFE phase								
No. of Stands	24	3	6	6	44	29	24	30	36	9	3	12	17	20	6
TREES															
Juni scop	(0)	(0)	-(0)	-(0)	(0)	(0)	(0)	(0)	-(0)	(0)	(0)	1(1)	1(0)	-(0)	3(1)
Pinu flex	+(1)	7(2)	2(1)	-(0)	-(0)	(0)	-(0)	+(1)	-(0)	1(37)	-(0)	-(0)	-(0)	-(0)	-(0)
Pinu pond	(0)	(0)	(0)	(0)	(0)	(0)	(0)	-(0)	(0)	(0)	(0)	1(1)	-(0)	-(0)	-(0)
Frax penn	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pseu menz	8(30)	3(3)	10(78)	-(0)	1(1)	1(0)	-(0)	+(3)	(0)	6(1)	(0)	8(1)	7(3)	5(6)	5(0)
Pinu cont	7(24)	7(74)	2(3)	(0)	7(18)	6(12)	4(3)	1(8)	(0)	1(0)	10(70)	10(60)	10(64)	10(56)	10(62)
Lari occi	-(0)	(0)	-(0)	(0)	-(0)	(0)	-(0)	-(0)	(0)	(0)	(0)	-(0)	1(1)	-(0)	-(0)
Pinu mont	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pice glau	1(30)	(0)	-(0)	5(37)	(0)	(0)	-(0)	+(0)	(0)	(0)	(0)	2(2)	1(0)	-(0)	-(0)
Pice enge	6(14)	3(0)	3(3)	3(8)	8(13)	8(12)	8(22)	7(10)	4(11)	2(0)	-(0)	3(1)	8(1)	4(1)	2(1)
Betu papy	-(0)	-(0)	-(0)	-(0)	(0)	(0)	-(0)	(0)	-(0)	(0)	(0)	-(0)	(0)	-(0)	-(0)
Abie gran	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)
Thuj plic	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)
Tsug hete	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Abie lasi	10(32)	10(33)	10(19)	10(50)	10(23)	10(29)	9(37)	10(27)	9(16)	7(0)	-(0)	7(3)	6(1)	6(3)	3(0)
Tsug mert	-(0)	-(0)	-(0)	-(0)	-(0)	+(3)	-(0)	-(0)	+(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pinu albi	5(10)	7(2)	3(2)	5(30)	10(33)	10(19)	8(15)	10(32)	9(14)	10(67)	3(1)	6(1)	4(1)	6(1)	5(5)
Lari lyal	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	5(35)	+(0)	10(47)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
SHRUBS AND SUBSHRUBS															
Alnu sinu	-(0)	-(0)	-(0)	-(0)	+(19)	(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	1(8)	1(3)	-(0)
Amel alni	+(1)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	2(1)	1(1)	1(1)	2(1)
Arte trid	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)
Holo disc	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Juni comm	3(1)	3(1)	2(1)	-(0)	3(2)	+(1)	-(0)	2(3)	1(1)	6(8)	3(1)	5(1)	5(2)	4(1)	7(1)
Juni hori	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	(0)	1(3)	-(0)	-(0)	-(0)	-(0)	-(0)
Ledu glan	-(0)	-(0)	-(0)	-(0)	+(3)	1(6)	1(3)	+(1)	3(7)	-(0)	-(0)	-(0)	1(15)	-(0)	-(0)
Menz ferr	-(0)	-(0)	-(0)	-(0)	+(0)	1(2)	9(44)	-(0)	(0)	(0)	-(0)	-(0)	1(0)	-(0)	-(0)
Oplo horr	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Pach myrs	-(0)	-(0)	-(0)	-(0)	(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)
Phyl empe	-(0)	-(0)	-(0)	-(0)	1(14)	2(7)	1(6)	1(9)	7(14)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Phys malv	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)
Prun virg	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Purs trid	-(0)	-(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	(0)	-(0)	10(18)	-(0)	-(0)	-(0)	-(0)
Ribe lacu	3(1)	3(0)	3(1)	-(0)	+(1)	1(1)	1(2)	1(1)	-(0)	-(0)	-(0)	-(0)	1(0)	1(1)	-(0)
Ribe mont	3(1)	-(0)	2(1)	10(14)	-(0)	-(0)	-(0)	+(3)	(0)	2(9)	-(0)	-(0)	-(0)	-(0)	-(0)
Rubu parv	1(2)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)
Shep cana	2(10)	-(0)	(0)	2(1)	-(0)	-(0)	-(0)	-(0)	-(0)	2(1)	-(0)	4(0)	7(5)	2(8)	2(1)
Spir betu	2(1)	7(1)	8(1)	-(0)	1(1)	+(1)	-(0)	-(0)	-(0)	1(1)	-(0)	5(1)	8(2)	7(3)	7(11)
Symp albu	+(0)	-(0)	3(19)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	2(1)	-(0)	2(1)
Taxu brev	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vacc caes	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	10(19)	2(0)	-(0)	-(0)
Vacc glob	1(1)	3(3)	3(1)	-(0)	4(7)	4(13)	6(12)	1(10)	1(1)	-(0)	-(0)	2(1)	5(29)	2(1)	2(1)
Vacc myrt	+(1)	-(0)	-(0)	-(0)	1(14)	1(31)	1(8)	+(63)	-(0)	-(0)	-(0)	2(8)	-(0)	1(3)	-(0)
Vacc scop	1(1)	7(3)	-(0)	2(3)	9(42)	10(36)	9(22)	7(35)	8(11)	2(50)	-(0)	5(18)	8(29)	10(58)	5(5)
Arct uva-	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	1(1)	10(1)	6(12)	6(2)	4(11)	5(18)
Berb repe	3(1)	3(1)	10(2)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	2(2)	-(0)	4(1)	5(1)	4(0)	7(1)
Linn bore	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(23)	10(28)	2(1)	2(1)
FERNS AND FERN ALLIES															
Athy fili	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Equi arve	-(0)	-(0)	-(0)	(0)	+(1)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)
Gymn dryo	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
GRAMINOIDS															
Agro scab	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	1(1)	-(0)	1(1)	-(0)
Agro spic	1(1)	3(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	3(2)	10(1)	-(0)	-(0)	-(0)	2(1)
Cala cana	1(1)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	1(3)	1(8)	-(0)	-(0)
Cala rube	2(1)	-(0)	7(2)	-(0)	1(1)	+(1)	-(0)	-(0)	-(0)	3(2)	-(0)	10(36)	10(23)	7(14)	10(36)
Care geye	3(3)	10(37)	10(42)	-(0)	6(11)	7(4)	2(1)	4(5)	1(7)	7(8)	-(0)	5(7)	2(1)	5(4)	7(11)
Fest idah	2(0)	3(1)	-(0)	2(1)	1(1)	-(0)	-(0)	2(3)	-(0)	6(12)	3(1)	2(1)	-(0)	-(0)	2(1)
Fest scab	-(0)	3(1)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	1(1)	-(0)	-(0)	-(0)
Hesp king	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Luzu hitc	-(0)	-(0)	-(0)	(0)	-(0)	10(10)	9(8)	3(24)	9(13)	-(0)	-(0)	-(0)	-(0)	1(0)	-(0)
Oryz aspe	+(1)	-(0)	-(0)	-(0)	(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Schi purp	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
FORBS															
Acta rubr	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)
Aden bico	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Aral nudi	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Arni cord	10(6)	3(1)	8(15)	3(9)	5(5)	1(2)	-(0)	2(2)	-(0)	2(26)	-(0)	7(2)	7(1)	6(3)	7(8)
Arni lati	2(8)	7(3)	2(63)	7(5)	8(9)	7(8)	8(7)	7(7)	6(5)	2(20)	-(0)	-(0)	3(18)	4(2)	-(0)
Bals sagi	-(0)	-(0)	2(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)
Clem pseu	+(0)	-(0)	2(1)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)
Clem tenu	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Clin unif	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)
Copt occi	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Corn cana	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(3)	-(0)	-(0)
Disp trac	1(1)	-(0)	5(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Gali bore	3(1)	(0)	7(1)	3(1)	1(1)	-(0)	-(0)	+(3)	-(0)	4(2)	-(0)	3(1)	1(1)	1(1)	2(1)
Gali trif	-(0)	3(1)	3(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)	-(0)
Gera rich	-(0)	-(0)	2(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	1(0)	1(0)	-(0)	-(0)
Hier grac	-(0)	3(1)	-(0)	2(1)	5(1)	4(0)	3(0)	6(1)	6(2)	1(3)	-(0)	-(0)	-(0)	1(1)	-(0)
Osmo chil	9(1)	3(1)	10(1)	7(1)	3(1)	1(1)	-(0)	2(1)	-(0)	7(0)	-(0)	-(0)	2(1)	1(1)	-(0)
Pyro asar	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	-(0)	-(0)	1(0)	-(0)	-(0)	-(0)
Pyro secu	8(1)	7(1)	10(1)	5(1)	4(1)	2(1)	3(0)	1(1)	-(0)	1(1)	-(0)	3(0)	7(0)	3(1)	2(1)
Pyro unif	-(0)	-(0)	-(0)	2(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Sene stre	3(1)	-(0)	-(0)	3(1)	+(1)	-(0)	-(0)	+(1)	-(0)	3(1)	3(1)	-(0)	1(1)	-(0)	3(1)
Sene tria	+(1)	-(0)	-(0)	-(0)	1(1)	1(1)	1(1)	1(2)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Smil race	+(1)	-(0)	7(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	(0)	1(1)	1(1)	-(0)	-(0)
Smil stel	+(1)	-(0)	5(1)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	1(1)	-(0)	-(0)
Stre ampl	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	+(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Thal occi	8(6)	7(2)	10(18)	-(0)	2(3)	2(1)	+(1)	1(1)	-(0)	2(9)	-(0)	3(1)	3(1)	1(3)	-(0)
Tiar trif	-(0)	-(0)	-(0)	-(0)	-(0)	+(1)	+(1)	-(0)	-(0)	(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Trol laxu	-(0)	-(0)	-(0)	-(0)	+(1)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Vale sitc	+(1)	-(0)	2(1)	-(0)	4(2)	4(1)	+(3)	1(1)	1(3)	1(1)	-(0)	-(0)	1(1)	2(0)	-(0)
Vera viri	-(0)	-(0)	2(1)	(0)	1(1)	3(1)	2(1)	+(1)	1(1)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Viol cana	-(0)	-(0)	2(3)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)	-(0)
Viol orbi	+(3)	-(0)	2(1)	-(0)	1(1)	4(1)	3(1)	1(1)	-(0)	-(0)	(0)	-(0)	2(1)	1(3)	-(0)
Xero tena	-(0)	-(0)	-(0)	-(0)	2(31)	9(27)	7(15)	4(14)	3(1)	1(1)	-(0)	1(0)	-(0)	3(1)	-(0)

*Code to constancy values + = 0-5%, 1 = 5-15%, 2 = 15-25%, 3 = 25-35%, 4 = 35-45%, 5 = 45-55%, 6 = 55-65%, 7 = 65-75%, 8 = 75-85%, 9 = 85-95%, 10 = 95-100%

APPENDIX C-2

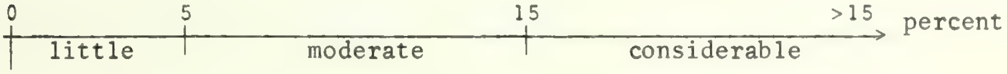
(See pocket inside back cover)

APPENDIX D-1

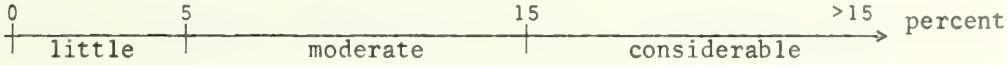
Soils data in the following four-page table are presented by habitat type and phase in a format similar to that for vegetative data (appendix C). COARSE FRAGMENT TYPES are shown as percentage of stands in which a given rock type was the apparent primary residual parent material. TEXTURAL CLASSES are also shown as percentage of stands having a given soil texture. All other categories of data are presented as mean values.

These appendix data and the individual stand data were used in writing the brief soil descriptions for series, habitat types, and phases. The terminology was based primarily on the USDA Soil Conservation Service (1975) definitions with some modifications. The basis for the adjectives as used in our text is:

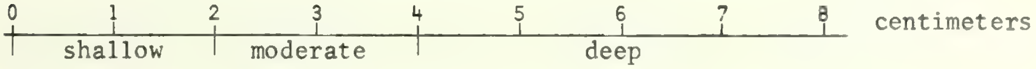
SURFACE ROCK EXPOSED (Includes cobbles, stones, and fixed rock; i.e., material >3 inches)



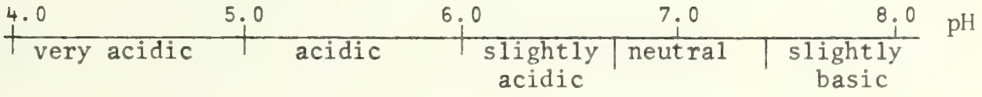
BARE SOIL EXPOSED (Includes soil and gravel; i.e., material <3 inches)



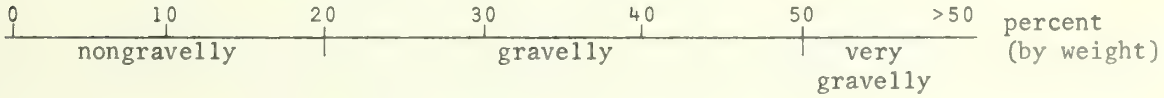
DUFF DEPTH



REACTION



GRAVEL CONTENT (Includes all coarse fragments <3 inches regardless of kind or shape



APPENDIX D-1

General soil characteristics (upper 10 cm) of Montana habitat types and phases (n = number of stands)

Soil characteristic	PINUS FLEXILIS SERIES				PINUS PONDEROSA SERIES									PSEUDOTSUGA MENZIESII SERIES											
	PIFL/AGSP h.t.	PIFL/FEID h.t.		PIFL/JUCO h.t.	PIPO/AGSP h.t.	PIPO/FEID h.t.		PIPO/PUTR h.t.		PIPO/SYAL h.t.		PIPO/PRVI h.t.		PSME/AGSP h.t.	PSME/FEID h.t.	PSME/FESC h.t.	PSME/VACA h.t.	PSME/PHMA h.t.		PSME/VAGL h.t.			PSME/LIBO h.t.		
		FEID phase	FESC phase			FEID phase	FESC phase	AGSP phase	FEID phase	SYAL phase	BERE phase	PRVI phase	SHCA phase					PHMA phase	CARU phase	VAGL phase	ARUV phase	XETE phase	SYAL phase	CARU phase	VAGL phase
	n = [illegible]	n = 6	n = 4	n = 6	n = 2[illegible]	n = 12	n = 15	n = 4	n = 7	n = 7	n = 3	n = [illegible]	n = 2	n = 11	n = 14	n = 13	n = [illegible]	n = [illegible]	n = [illegible]	n = [illegible]	n = [illegible]	n = [illegible]	n = [illegible]	n = [illegible]	n = [illegible]
	COARSE FRAGMENTS (in percent occurrence)																								
SEDIMENTARY																									
Calcareous	67	[illegible]	[illegible]	83	[illegible]	[illegible]	34	[illegible]	43	17	100	-	-	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]					[illegible]	
Noncalcareous	33	[illegible]		17	[illegible]	25	33			34		100	100	[illegible]	17	[illegible]	4[illegible]	[illegible]	[illegible]	[illegible]	13			[illegible]	[illegible]
METAMORPHIC																									
Calcareous argillite							-		29	-		--	-			8			-					[illegible]	
Argillite	--	-	--	--	[illegible]	[illegible]	13	--	14	-				18	-	46	41	2		[illegible]	.1			[illegible]	
Quartzite	--		-	--	5	[illegible]	13	--	--	--	--	--	--	18	[illegible]	8	-	-	-	1[illegible]					.1
Gneiss & schist	--	17		--	--	[illegible]	--	--	--	--	--	--	--	[illegible]	[illegible]		-	[illegible]		[illegible]					[illegible]
Miscellaneous	--	17		--	--	--	--	--	--	--	--	--	--	--		8	.	[illegible]	2	[illegible]	4	.	..		
IGNEOUS																									
Basalt & andesite	--	--	-	--	--	--			--		--	--	--	--	--	--	[illegible]		-					[illegible]	
Quartz monzonite	--	--	--		--	6	7	50	-	17	--		--	--	20		9	-	1		11				.1
Rhyolite			--		-	--	--		14	33		-	-		-			[illegible]						.	
Granite & biotite granite		-							-		--	--		18	13		-		--					[illegible]	
Miscellaneous			-							-	--	-		[illegible]											.
MIXED															.			3		11	14				
	GROUND SURFACE																								
SURFACE ROCK EXPOSED (mean %)	18	12	3	[illegible]	3	[illegible]	8	4	[illegible]	[illegible]	1	1	0	11	9	5	1	[illegible]	5	[illegible]	[illegible]	1	1	[illegible]	[illegible]
BARE SOIL EXPOSED (mean %)	25	8	[illegible]	1	7	2	3	17	6	1	0	0	0	13	9	7	[illegible]		1		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LITTER DEPTH (mean cm)	[illegible] 5	1.2	1.2	3.2	3.4	3.6	4.4	0.5	2.4	4.5	5.3	5.8	3.5	2.5	2.4	[illegible]	4.3	4.2	3.[illegible]	3.1	[illegible]	3.3	3.6	[illegible]	[illegible]
	UPPER SOIL																								
REACTION (mean pH)	7.1	6.8	6.8	7.1	6.5	6.[illegible]	6.3	6.1	7.0	6.3	7.0	6.3	5.9	6.6	6.2	6.1	[illegible]	6.2	[illegible]	5.[illegible]	[illegible]	[illegible]	6.[illegible]	[illegible]	[illegible]
GRAVEL CONTENT (mean %)	38	36	24	27	33	31	41	33	24	31	3	19	25	42	32	37	2[illegible]	44	38	47	36	[illegible]	31	[illegible]	34
TEXTURAL CLASS (percent occurrence)																									
Loamy sand				-	5	--			--	14	-	--	--	18	--			3			--				
Sandy loam		17	25	--	5	9	7		29	29	--	--	--	27	21	--	76	1[illegible]	[illegible]			1[illegible]	1[illegible]	[illegible]	[illegible]3
Loam	67	33	50	17	29	36	20		29	--				18	43	27	24	31	40	4[illegible]		14	[illegible]	3[illegible]	17
Silt loam & silt	33	50	25	67	56	55	73		43	29	67	100	100	36	36	73		56	[illegible]	58		44	[illegible]	3[illegible]	[illegible]
Silty clay loam & clay loam	-	--	-	17	5	-	--	-	--	29	33	--	-	--						-	100			2[illegible]	

con

APPENDIX D-1 (con.)

Soil characteristics	PSEUDOTSUGA MENZIESII SERIES (con.) PSME/SYAL h.t. AGSP phase n = 6	PSME/SYAL h.t. CARU phase n = 38	PSME/SYAL h.t. SYAL phase n = 14	PSME/CARU h.t. AGSP phase n = 9	PSME/CARU h.t. ARUV phase n = 8	PSME/CARU h.t. CARU phase n = 50	PSME/CARU h.t. PIPO phase n = 11	PSME/CAGE h.t. n = 9	PSME/SPBE h.t. n = 1[illegible]	PSME/ARUV h.t. n = [illegible]	PSME/JUCO h.t. n = 9	PSME/ARCO h.t. n = 11	PICEA/EOAR h.t. n = 3	PICEA SERIES PICEA/CLUN h.t. VACA phase n = 4	PICEA/CLUN h.t. CLUN phase n = 4	PICEA/PHMA h.t. n = 3	PICEA/GATR h.t. n = 1[illegible]	PICEA/VACA h.t. n = [illegible]	PICEA/LIBO h.t. n = [illegible]	PICEA/SMST h.t. n = [illegible]	ABIES GRANDIS SERIES ABGR/CLUN h.t. CLUN phase n = [illegible]	ABGR/CLUN h.t. ARNU phase n = [illegible]	ABGR/CLUN h.t. XETE phase n = 3	ABGR/LIBO h.t. XETE phase n = [illegible]
COARSE FRAGMENTS (in percent occurrence)																								
SEDIMENTARY																								
Calcareous	34	8	35	33		6	9	33	18	57	22	9	67			67	[illegible]		[illegible]			-	-	
Noncalcareous	17	29	14			16	36	33	45	14	22	27		-	[illegible]		[illegible]	50			[illegible]	[illegible]		10
METAMORPHIC																								
Calcareous argillite	--	-	--	--	--	--	-	--	9	-		-				-	-	-			[illegible]		--	-
Argillite	17	16	21	22	13	16	-	22	18	14		9		[illegible]	57			50		17		[illegible]		
Quartzite	-	11	-	22	13	6	18	-	9	14	--	9	--		14		-	-			--		--	
Gneiss & schist	17	1[illegible]	14	11		8	9	11							--	-	[illegible]	--	[illegible]		[illegible]	--		
Miscellaneous	17	6	-	11	13	4	9	--		-	--	-	--	25									[illegible]	
IGNEOUS																								
Basalt & andesite		3	-		--	7	--	--	-		11	--	-			33	[illegible]	-	[illegible]				--	
Quartz monzonite	-	13	--	--	50	7	18	-					-	--	--		-						-	
Rhyolite		3	7		13	7		-	--	--	11	18			-		[illegible]		[illegible]	[illegible]				
Granite & biotite granite	-	[illegible]				7					22	18	--	--						[illegible]		--		
Miscellaneous	-	6	7	--	-	6		--	--		11	9	33				10		[illegible]				[illegible]	
MIXED	-	--	--	-	--	3	--	--	--	-	-	-	-					--	-					
GROUND SURFACE																								
SURFACE ROCK EXPOSED (mean %)	7	1	3	5	6	2	3	1	5	1	3	4	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		1	[illegible]	[illegible]	[illegible]	[illegible]
BARE SOIL EXPOSED (mean %)	2	[illegible]	1	[illegible]	2	1	0	1	2	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]			1		[illegible]	
DUFF DEPTH (mean cm)	2.6	3.6	4.1	3.7	3.5	4.1	4.5	4.7	2.5	6.0	1.2	4.3	7.3	2.6	6.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.1	[illegible]	[illegible]	[illegible]
UPPER SOIL																								
REACTION (mean pH)	6.4	5.9	6.5	6.0	5.6	5.7	5.7	6.2	6.3	[illegible]	5.8	[illegible]	6.8	5.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GRAVEL CONTENT (mean %)	[illegible]	[illegible]	[illegible]	[illegible]	24	[illegible]	36	42	[illegible]	36	27	30	[illegible]	19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TEXTURAL CLASS (percent occurrence)																								
Loamy sand		3							-	--	-	-		-	-			--						
Sandy loam		[illegible]		11	38	13	36	11	18	-	[illegible]	[illegible]	[illegible]						[illegible]		--			
Loam	[illegible]	[illegible]	57	44	[illegible]	37	[illegible]	33	27	57	25	16	--	25	[illegible]		[illegible]	[illegible]	[illegible]				[illegible]	
Silt loam & silt	[illegible]	4	43	44	[illegible]	53	15	56	[illegible]	43	[illegible]	36	67	75	[illegible]	[illegible]	[illegible]					[illegible]		[illegible]
Silty clay loam & clay loam	-	[illegible]	--	--	-			--				-	--	--	--	-			-		11		[illegible]	

con.

APPENDIX [illegible]

[illegible]	[illegible] ABLA/CACA [illegible]
	COARSE FRAGMENTS (percent occurrence)
SEDIMENTARY	
[illegible]	[illegible]
Non-calcareous	[illegible]
METAMORPHIC	
[illegible]	[illegible]
Argillite	[illegible]
Quartzite	[illegible]
Gneiss & schist	[illegible]
Miscellaneous	[illegible]
IGNEOUS	
Basalt & andesite	[illegible]
Quartz monzonite	[illegible]
Rhyolite	[illegible]
Granite & biotite granite	[illegible]
Miscellaneous	[illegible]
MIXED	[illegible]
	GROUND SURFACE
SURFACE ROCK EXPOSED (mean %)	[illegible]
BARE SOIL EXPOSED (mean %)	[illegible]
LITTER DEPTH (mean cm)	[illegible]
	UPPER SOIL
REACTION (mean pH)	[illegible]
GRAVEL CONTENT (mean %)	[illegible]
TEXTURAL CLASS (percent occurrence)	
Loamy sand	[illegible]
Sandy loam	[illegible]
Loam	[illegible]
Silt loam & silt	[illegible]
Silty clay loam & clay loam	[illegible]

APPENDIX D-1 (con.)

Soil characteristics	ABIES LASIOCARPA SERIES (con.)																				PINUS CONTORTA SERIES			
	ABLA/XETE h.t. VAGL phase n = 28	ABLA/XETE h.t. VASC phase n = 19	TSME/XETE h.t. n = 3	ABLA/VAGL h.t. n = 13	ABLA/VASC h.t. CARU phase n = 6	ABLA/VASC h.t. VASC phase n = 11	ABLA/VASC h.t. THOC phase n = 8	ABLA/ALSI h.t. n = 5	ABLA/CARU h.t. n = 10	ABLA/CLPS h.t. n = 11	ABLA/ARCO h.t. n = 17	ABLA/CAGE h.t. CAGE phase n = 3	ABLA/CAGE h.t. PSME phase n = 2	ABLA/RIMO h.t. n = 3	ABLA-PIAL/VASC h.t. n = 22	ABLA/LUHI h.t. VASC phase n = 25	ABLA/LUHI h.t. MEFE phase n = 13	TSME/LUHI h.t. VASC phase n = 2	PIAL/ABLA h.t. n = 15	PIAL h.t. n = 5	PICO/VACA h.t. n = 11	PICO/LIBO h.t. n = 14	PICO/VASC h.t. n = 17	PICO/CARU h.t. n = 4
											COARSE FRAGMENTS (in percent occurrence)													
SEDIMENTARY																								
Calcareous		5		8	10	9	--	-	34	100	21	33	50	25	9	--	--	--	7	40			-	--
Noncalcareous	26	26	33	16	20		25	20	17		28	--	50	50	32	20	54	100	57	40	27	21	12	
METAMORPHIC																								
[illegible] & argillite	--	--	-						--				--	--	-	-	-	--	--	--	--	--	-	-
Argillite	30	21	--	8	-	18	25	20	--	--	--		--	--		16	8	--	36				12	--
Quartzite	7	11	--	--	--	9	13	--	-	--	--	--	-	--	5	12			--	--	18	14	6	
Gneiss & schist	15	5		15		9	13	20	17		21	33	-	25	23	16	-	--	-	--		14	6	--
Miscellaneous	--	10	67	16			13			-	14		--		3	12	15	-				--	6	--
IGNEOUS																								
Basalt & andesite				8	10	9	--	-	-		7		-	--	-		-	--	--			7	6	-
Quartz monzonite	7	5			10	27					7				9	16	8	-	--	--	45	14	35	50
Rhyolite	4	11	--	8	10		--	-	-	--	--	--	--	--	5	8	8	--	--	20	-	7	6	25
Granite & biotite granite	--		-	15	30	-	--	20	--	-	-	33	-	--	14			-	--	--	9	14	12	25
Miscellaneous		5		8	10	18	13	20	34				-		-	4	8					7	--	--
MIXED								-						-	--	--			--	--	--	--	--	
											GROUND SURFACE													
SURFACE ROCK EXPOSED (mean %)	1	3	1	3	2	3	1	1	0	1	2	2	1	1	4	3	3	2	17	2	1	2	5	2
BARE SOIL EXPOSED (mean %)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	6	3	0	0	0	1
DUFF DEPTH (mean cm)	3.3	3.8	2.0	5.3	4.5	3.5	5.6	6.0	4.3	4.2	3.9	4.7	6.7	7.5	4.4	3.9	4.4	2.5	2.8	2.7	4.8	6.4	4.7	2.6
											UPPER SOIL													
REACTION (mean pH)	5.1	4.6	4.8	5.1	5.2	5.1	5.0	4.9	5.5	6.7	5.7	5.2	5.9	4.6	5.0	4.8	4.4	4.7	4.9	6.0	4.9	5.3	[illegible]	5.6
GRAVEL CONTENT (mean %)	37	36	21	36	19	28	15	18	21	21	19	19	12	2	26	32	31	42	45	25	16	21	26	22
TEXTURAL CLASS (percent occurrence)																								
Loamy sand	4	-					-	-	-		-	-		--	--	--	-	--	--	--	9	14	--	-
Sandy loam	[illegible]	5		--	22	13	--	-	20				--	--	14	4	15	--		-	9	7	25	25
Loam	50	47		31	22	63	33	80	20	--	15	67	-		32	58	31	50	50	--	27	36	[illegible]	
Silt loam & silt	36	47	100	62	56	22	67	20	60	70	77	33	100	100	50	38	54	50	50	100	[illegible]	43	25	75
Silty clay loam & clay loam	--			8	--	--	--	--	--	30	8	--	--	--	5				-			-		

APPENDIX D-2

Climatic parameters for stations within selected habitat types in or near Montana (from U. S. Weather Service records unless footnoted) (~ = approximately)

Climax series and station	Estimated habitat types and phase		Mean monthly temperature July	Mean monthly temperature Jan.	Average number of frosts (32°F): June-August	Mean annual precipitation	Mean May-Aug. precipitation	Mean annual snowfall	Township : Range : Section	Elevation
			°F(°C)	°F(°C)		Inches	Inches	Inches		Feet
PINUS FLEXILIS SERIES										
Townsend (near)	AGSP	-	66(19)	17(-8)	1	10.4	6.0	~45	7N2ES31	3,833
Blackleaf (near)	FEID	FESC	60(16)	21(-6)	~5	14.6	8.3	--	26N7WS18	4,600
PINUS PONDEROSA SERIES										
Roundup	AGSP	-	72(22)	24(-4)	0	10.9	6.5	~36	8N25ES13	3,227
Plains	FEID	FEID	67(19)	25(-4)	7	14.0	5.4	~42	20N26WS26	2,473
Canyon Ferry	PUTR	--	71(22)	26(-3)	[illegible]	12.1	6.8	~39	10N1WS3	3,850
Lewistown AP	SYAL	--	66(19)	20(-7)	1	16.5	9.6	61	15N18ES20	4,130
PSEUDOTSUGA MENZIESII SERIES										
Libby RS	SYAL		66(19)	22(-6)	3	18.5	4.5	--	31N31WS34	2,080
Lincoln RS	SYAL	--	61(16)	17(-8)	14	19.4	7.4	~100	14N9WS24	4,500
Pleasant Valley	VACA	--	60(16)	20(-7)	16	18.9	5.6	—	27N26WS2	3,600
Greenough[1]	VACA	--	63(17)	18(-8)	9	17.8	6.1	~110	13N15WS14	4,000
Lubrecht 1.5[1]	CARU	ARUV	63(17)	22(-6)	3	--	4.7	--	13N14WS15	4,350
PICEA SPP. SERIES										
Polebridge	CLUN	VACA	61(16)	17(-8)	14	23.1	6.3	122	35N21WS27	3,690
Yellowstone NE entrance	LIBO	--	56(13)	14(-10)	29	25.7	9.7	169	9S14ES34	7,200
ABIES GRANDIS, THUJA, TSUGA SERIES										
Trout Cr. 2W	ABGR/CLUN	-	64(18)	23(-5)	4	30.0	5.5	~90	24N32ES24	2,480
Heron 2NW	TSHE/CLUN	CLUN	64(18)	24(-4)	2	34.3	6.5	87	27N34WS29	2,240
ABIES LASIOCARPA SERIES										
Lower subalpine h.t.s										
West Glacier	CLUN	VACA	64(18)	21(-6)	1	28.1	8.0	129	32N19WS36	3,154
Seeley Lake RS	CLUN	XETE	63(17)	17(-8)	6	21.1	6.5	120	17N15WS21	4,030
Roland, Idaho	CLUN	MEFE	62(17)	23(-5)	1	53.8	7.6	274	47N6ES35,ID	4,150
Burke, Idaho	MEFE	-	60(16)	22(-6)	3	48.6	9.1	234	48N5ES11,ID	4,093
Summit (U.S. Hwy. 2)	XETE	VASC	57(14)	15(-9)	18	36.9	9.3	253	30N14WS34	5,213
Kings Hill	VASC	-	59(15)	16(-9)	13	28.7	11.1	270	13N8ES34	7,300
Upper subalpine and timberline h.t.s:										
Hell's Half Acre, Idaho[2]	ABLA/LUHI	VASC	58(14)	--	~8	~40	--	--	27N16ES29	8,117
McCalla Lake[3]	LALY-ABLA	--	53(12)	14(-10)	~16	45	--	~300	9N21WS28	8,000
Old Glory Mtn., B.C.[4]	~PIAL-ABLA[5]	--	49(9)	12(-11)	~18	28.3	--	212	49° 09' N 117° 55' W	7,700

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[1] Steele 1972.
[2] Maintained by Bitterroot National Forest, Forest Service, Hamilton, Montana.
[3] Arno 1970.
[4] Canadian Department of Transport 1967.
[5] Located about 500 feet in elevation above timberline.

APPENDIX E-1

Mean basal areas and 50-year site indexes for Montana stands by habitat type. Means are shown where n = 3 or more, confidence limits (95 percent) for estimating the mean are given where n = 5 or more

	West-side (Kootenai, Flathead, Lolo, and Bitterroot National Forests)							
	Basal area:	Site index by species						
Habitat type	(ft^2/acre)	PIPO	PSME	PICO	LAOC	PICEA	ABGR	ABLA
SCREE	156 ± 73	44 ± 8	38 ± 6				.	
PIFL/AGSP	.	.		.	.			.
PIFL/FEID	.	.	.			.	.	
PIFL/JUCO	.	.	.	.	.		.	.
PIPO/AGSP	101 ± 25	45 ± 9	.				.	
PIPO/FEID	139 ± 21	46 ± 5	.		.		.	
PIPO/PUTR	77 ± 28	45 ± 14	.		.			.
PIPO/SYAL	170 ± ?	44 ± ?		.	.		.	.
PIPO/PRVI	.	.	.	.		.	.	.
PSME/AGSP	.	.	.	.	.	.	.	.
PSME/FEID	.	.	.	.	.	.		
PSME/FESC	126 ± 47	36 ± ?	44 ± 7	.		.	.	.
PSME/VACA	192 ± 33	62 ± 8	51 ± 6	57 ± 8	39 ± 5		.	
PSME/PHMA	153 ± 20	59 ± 14	58 ± 6	48 ± ?	57 ± ?			.
PSME/VAGL	185 ± 33	.	44 ± 4	.	.		.	.
PSME/LIBO	226 ± 53	.	56 ± 6	50 ± 9	55 ± ?	.	.	
PSME/SYAL	172 ± 23	54 ± 5	52 ± 4	.	.		.	.
PSME/CARU	191 ± 24	50 ± 8	47 ± 6	48 ± ?			.	.
PSME/CAGE	186 ± ?	.	.	.	.			
PSME/SPBE	142 ± ?	63 ± ?	49 ± ?	.	.		.	.
PSME/ARUV	.	.	.	.	.		.	
PSME/JUCO	.	.		.	.	.	.	.
PSME/ARCO	.	.	.	.	.	.	.	.
PICEA/EQAR	.	.	.	.	.	.	.	.
PICEA/CLUN	241 ± 38	.	60 ± ?	60 ± 2	.	69 ± 6	.	.
PICEA/PHMA	.	.	.	.	.	.	.	.
PICEA/GATR	.	.	.	.	.	.	.	.
PICEA/VACA		.	.	65 ± ?	74 ± ?	64 ± ?	.	.
PICEA/SEST	.	.	.	.		.	.	.
PICEA/LIBO	.	.	.	.	.	.	.	.
PICEA/SMST	.	.	.	.		.	.	.
ABGR/CLUN	254 ± 94	.	71 ± ?	.	.	73 ± ?	58 ± 15	.
ABGR/LIBO	195 ± ?	.	.	.	.	.	54 ± ?	.
THPL/CLUN	305 ± 96	.	66 ± ?	.	63 ± ?	72 ± 14	61 ± ?	74 ± ?
TSHE/CLUN	267 ± 55	(PIMO--62 ± ?)		.	80 ± ?	77 ± ?	50 ± ?	
ABLA/OPHO	351 ± ?	.	.	.	.	69 ± ?	.	.
ABLA/CLUN	248 ± 24	.	66 ± 7	60 ± 5	63 ± 6	66 ± 6	55 ± 9	59 ± 6
ABLA/GATR	196 ± 47	.	.	50 ± 12	.	58 ± 9	.	67 ± 22
ABLA/VACA	.	.	.	.	.	.	.	.
ABLA/CACA	177 ± ?	.	.	50 ± 7	.	51 ± 5	.	48 ± ?
ABLA/LIBO	166 ± 35	.	46 ± 9	55 ± 7	56 ± ?	.		53 ± 12
ABLA/MEFE	172 ± 26	.	50 ± 8	56 ± 6	67 ± ?	60 ± 10	.	57 ± 9
ABLA/XETE	188 ± 26	.	40 ± 6	45 ± 6	51 ± ?	56 ± ?	.	47 ± 6
TSME/XETE	114 ± ?	.	.	.	.	.	.	.
ABLA/VAGL	.	.	.		.	.	.	
ABLA/VASC, THOC	.	.	.	.	.	.		.
ABLA/VASC, other	.	.	.	.	.	.	.	
ABLA/ALSI		.	.			.	.	.
ABLA/CARU	.	.	.		.	.	.	
ABLA/CLPS	.	.	.	.	.	.	.	.
ABLA/ARCO	.	.	.	.	.	.	.	
ABLA/CAGE	.	.	.	.	.	.	.	.
ABLA/RIMO	.			.	.	.	.	
ABLA-PIAL/VASC	.	.	.	.	.	.	.	.
ABLA/LUHI	187 ± 30	.	.	35 ± 8		43 ± 9	.	31 ± 5
PIAL-ABLA	146 ± 49	.	.		.	.	.	16 ± ?
LALY-ABLA	.	.	.		.	20 ± ?		14 ± 4
PIAL	.			.	.	.	.	.
PICO/PUTR h.t.	.	.	.	.	.	.		
PICO/VACA c.t.	.					.	.	
PICO/LIBO c.t.				.				
PICO/VASC c.t.	.		.	.		.	.	
PICO/CARU c.t.	.	.			.	.		

	East-side (Deerlodge, Beaverhead, Helena, Lewis and Clark, Gallatin, and Custer National Forests)					
	Basal area:	Site index by species				
Habitat type	(ft^2/acre)	PIPO	PSME	PICO	PICEA	ABLA
SCREE	64 ± 24		21 ± ?			
PIFL/AGSP	89 ± 40	.				
PIFL/FEID	91 ± 23		24 ± ?			
PIFL/JUCO	139 ± 79		25 ± 7			
PIPO/AGSP	111 ± 17	30 ± 10	.			
PIPO/FEID	135 ± 36	29 ± 12				
PIPO/PUTR	96 ± ?	26 ± ?				
PIPO/SYAL	168 ± 42	41 ± 6				
PIPO/PRVI	140 ± 10	47 ± ?				
PSME/AGSP	133 ± 38	34 ± ?	29 ± 4			
PSME/FEID	128 ± 39		32 ± 5			
PSME/FESC	159 ± 85		22 ± ?			
PSME/VACA	191 ± 130			47 ± ?		
PSME/PHMA	182 ± 32		43 ± 8	.		
PSME/VAGL	163 ± 37		41 ± ?	48 ± 13		
PSME/LIBO	192 ± 56	.	.	47 ± ?		
PSME/SYAL	196 ± 26	43 ± 11	41 ± 4	46 ± 7		
PSME/CARU	206 ± 19	45 ± ?	38 ± 3	43 ± 4		
PSME/CAGE	253 ± 67		36 ± ?		.	
PSME/SPBE	195 ± 62	.				
PSME/ARUV	138 ± 35	41 ± 17	28 ± 7			
PSME/JUCO	196 ± 34	.	40 ± ?	41 ± 6		
PSME/ARCO	210 ± 44	.	36 ± 4			
PICEA/EQAR	203 ± 45		.		51 ± 11	
PICEA/CLUN	.	.				
PICEA/PHMA	199 ± ?	.	58 ± ?		50 ± ?	
PICEA/GATR	234 ± 41	.		53 ± ?	58 ± 7	
PICEA/VACA						
PICEA/SEST	.	.	.		29 ± ?	
PICEA/LIBO	177 ± 17	.	40 ± ?	49 ± 4	52 ± [illegible]	
PICEA/SMST	224 ± 40		44 ± 8		53 ± 14	
ABGR/CLUN	.				.	
ABGR/LIBO	.			.	.	
THPL/CLUN	.	.				
TSHE/CLUN	.					.
ABLA/OPHO	.		.		.	.
ABLA/CLUN	203 ± 73	.	.	.	44 ± 8	40 ± ?
ABLA/GATR	244 ± 27	.	46 ± ?	43 ± ?	53 ± 6	47 ± 5
ABLA/VACA	177 ± 33		.	47 ± 3	47 ± ?	
ABLA/CACA	247 ± 56	.	.	50 ± 13	45 ± 4	43 ± 5
ABLA/LIBO	191 ± 20	.	43 ± 9	46 ± 11	44 ± [illegible]	43 ± 11
ABLA/MEFE	195 ± 41		.	.	[illegible] ± ?	[illegible] ± ?
ABLA/XETE	226 ± 39	.		43 ± ?		.
TSME/XETE		.				
ABLA/VAGL	201 ± 33	.	.	42 ± 4	43 ± ?	42 ± [illegible]
ABLA/VASC, THOC	295 ± 33			45 ± 4	46 ± 11	40 ± 7
ABLA/VASC, other	175 ± 20		.	40 ± [illegible]	45 ± 7	[illegible]
ABLA/ALSI		.		.	50 ± ?	46 ± [illegible]
ABLA/CARU	222 ± 85	.	40 ± 10	.	57 ± ?	50 ± 12
ABLA/CLPS	268 ± 51	.	30 ± ?		33 ± 5	40 ± 7
ABLA/ARCO	220 ± 41	.	43 ± 6	41 ± 3	43 ± 7	47 ± 3
ABLA/CAGE	.	.		.		[illegible]
ABLA/RIMO	.		.	.		40 ± ?
ABLA-PIAL/VASC	245 ± 24	.		33 ± 3	31 ± 3	[illegible] ± 3
ABLA/LUHI	236 ± 73		.	.	38 ± 17	34 ± 8
PIAL-ABLA	247 ± 63					25 ± ?
LALY-ABLA	.	.			.	
PIAL	[illegible]					21 ± [illegible]
PICO/PUTR h.t.	131 ± ?	.	.	40 ± ?		
PICO/VACA c.t.	184 ± 27			[illegible]		
PICO/LIBO c.t.	193 ± 29			52 ± 7		
PICO/VASC c.t.	166 ± 22	.		41 ± 4		
PICO/CARU c.t.	159 ± 22			47 ± [illegible]		

APPENDIX E-2

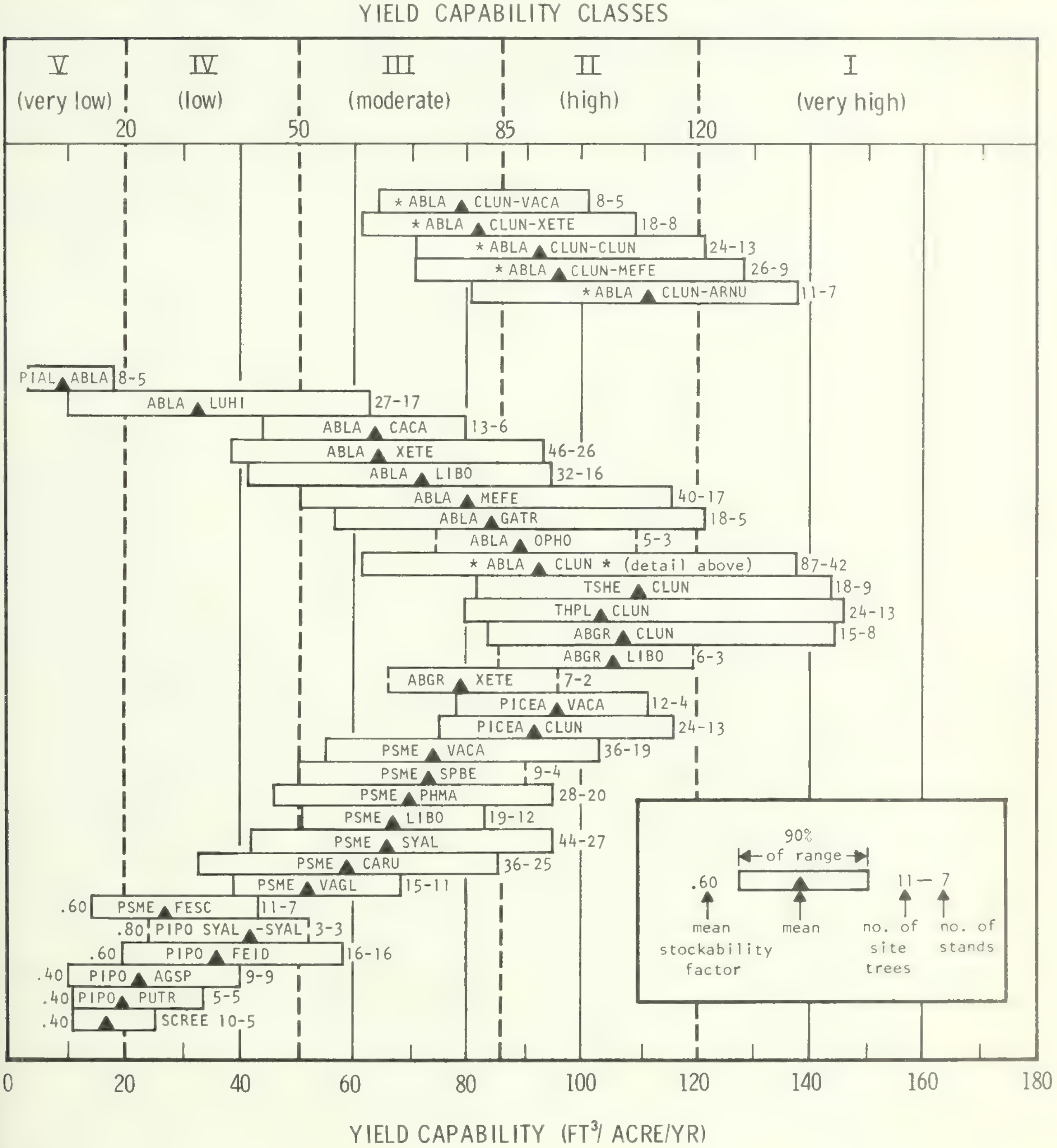
Mean maximum heights (in feet) for Montana stands by tree species and habitat type. Means are shown where n = 3 or more; confidence limits (95 percent) for estimating the mean are given where n = 5 or more.

Habitat type	Maximum height by species for the west-side (Kootenai, Flathead, Lolo, and Bitterroot National Forests)						
	PIPO	PSME	PICO	LAOC	PICEA	ABLA	PIAL
SCREE	[illegible]						
PIFL/AGSP							.
PIFL/FEID							
PIFL/JUCO							
PIPO/AGSP							
PIPO/FEID	[illegible]						
PIPO/SYAL							
PIPO/PRVI							
PSME/AGSP							
PSME/FEID					.		.
PSME/FESC	89 ± ?	77 ± ?					.
PSME/VACA	[illegible]	104 ± 7		128 ± 14			
PSME/PHMA	118 ± [illegible]	101 ± ?					
PSME/VAGL	[illegible] ± 10	85 ± 11					.
PSME/LIBO		8[illegible] ± ?		1[illegible]6 ± 17	.	.	.
PSME/SYAL	113 ± 15						
PSME/CARU	[illegible] ± 7	91 ± 6	.				.
PSME/CAGE					.		.
PSME/SPBE							.
PSME/ARUV							
PSME/JUCO				.			
PSME/ARCO		.					
PICEA/EQAR							.
PICEA/CLUN				130 ± 8	.	.	
PICEA/PHMA						.	.
PICEA/GATR							
PICEA/SEST		.		.			
PICEA/LIBO							
PICEA/SMST		.					.
ABGR/CLUN		107 ± ?					
ABGR/LIBO		98 ± ?	.	117 ± ?			.
THPL/CLUN		127 ± ?		149 ± 21	141 ± ?	135 ± ?	
TSHE/CLUN	.			129 ± 21	141 ± ?		
ABLA/CLUN		124 ± 9		133 ± ?	132 ± 32	120 ± ?	.
ABLA/GATR		.				.	
ABLA/CACA			94 ± 1[illegible]		115 ± ?		
ABLA/LIBO	.	101 ± ?		113 ± ?		.	
ABLA/MEFE		95 ± ?	88 ± 8	106 ± 17	109 ± 7	96 ± 10	
ABLA/XETE		86 ± 8	82 ± 7	96 ± 10			
ABLA/VAGL	.						
ABLA/VASC, THOC	.						
ABLA/VASC, other		.					
ABLA/CARU					.		
ABLA/CLPS	.					.	
ABLA/ARCO							.
ABLA/CAGE, PSME						.	
ABLA-PIAL/VASC	.			.		.	.
ABLA/LUHI			67 ± 9		[illegible]4 ± 11	70 ± 8	64 ± 6
PIAL-ABLA							55 ± 8
LALY-ABLA	.				54 ± 10	46 ± ?	
PIAL	.				.	.	.
PICO/VACA c.t.					.		
PICO/LIBO c.t.						.	.
PICO/VASC c.t.					.	.	.

Habitat type	Maximum height by species for the East side (Deerlodge, Beaverhead, Helena, Lewis and Clark, Gallatin, and Custer National Forests)						
	PIFL	PIPO	PSME	PICO	PICEA	ABLA	PIAL
SCREE	30 ± ?		58 ± ?	.		.	.
PIFL/AGSP	31 ± 12	.	.	.			
PIFL/FEID	39 ± 8	.	43 ± 14			.	.
PIFL/JUCO	35 ± 11	.	39 ± ?		.	.	.
PIPO/AGSP		57 ± 12		.		.	.
PIPO/FEID		74 ± 10	.	.		.	.
PIPO/SYAL	.	76 ± ?		.	.	.	.
PIPO/PRVI		83 ± 8	.	.		.	
PSME/AGSP		69 ± 19	60 ± 8	.		.	.
PSME/FEID		.	65 ± 8	.		.	.
PSME/FESC	.	67 ± ?	58 ± ?	.	.	.	.
PSME/VACA	.			.	.	.	.
PSME/PHMA	.		75 ± 12	.	.	.	.
PSME/VAGL	.	.	.	71 ± ?		.	.
PSME/LIBO	.		82 ± 6	.	.	.	.
PSME/SYAL	.		87 ± 10	.		.	.
PSME/CARU	.		77 ± 4	71 ± 8	.	.	.
PSME/CAGE		.	76 ± 13	.		.	.
PSME/SPBE		.	57 ± ?	.	.	.	.
PSME/ARUV		76 ± 14	.	.	.	.	.
PSME/JUCO			69 ± 13	.	.	.	.
PSME/ARCO	.	.	73 ± 8	.		.	.
PICEA/EQAR		.		.	110 ± 7	.	.
PICEA/CLUN	.	.		.	.	.	.
PICEA/PHMA	.	.	86 ± ?	.	.	.	.
PICEA/GATR		.		.	109 ± ?	.	.
PICEA/SEST	.		.	.	54 ± 11	.	.
PICEA/LIBO	.	.	87 ± ?	88 ± 11	99 ± ?	.	.
PICEA/SMST	.	.	89 ± ?	.	.	.	.
ABGR/CLUN	.	.		.	.	.	.
ABGR/LIBO	.	.	.	.		.	.
THPL/CLUN	.	.	.		.	.	.
TSHE/CLUN	.	.	.		.	.	.
ABLA/CLUN	.		.	.	.	.	.
ABLA/GATR	.		95 ± 17	84 ± 9	102 ± 5	88 ± ?	.
ABLA/CACA	.		.	79 ± 10	101 ± 8	.	.
ABLA/LIBO	.	.	86 ± 8	83 ± 8	.	.	.
ABLA/MEFE	.		.	82 ± 12	99 ± 11	87 ± ?	.
ABLA/XETE	.			71 ± 10	90 ± 27	.	.
ABLA/VAGL	.		79 ± ?	80 ± 8	.	.	.
ABLA/VASC, THOC	.		.	77 ± 6	90 ± 10	.	.
ABLA/VASC, other	.		.	71 ± 4	75 ± ?	.	
ABLA/CARU	.	.	82 ± 10	.	.	.	.
ABLA/CLPS	.	.	64 ± 7	.	70 ± 8	.	.
ABLA/ARCO	.	.	81 ± 9	78 ± ?	80 ± ?	.	
ABLA/CAGE, PSME	.	.	89 ± 13	.	.	82 ± ?	.
ABLA-PIAL/VASC	.	.	.	66 ± 8	76 ± 8	60 ± 7	57 ± 5
ABLA/LUHI			.	.	.	.	.
PIAL-ABLA	.				45 ± 15	20 ± 6	42 ± 7
LALY-ABLA	.		.	.	.	.	
PIAL	.	.	.	.	.	.	52 ± ?
PICO/VACA c.t.	.		.	83 ± 7	.		.
PICO/LIBO c.t.	.	.	.	92 ± 9	.	.	.
PICO/VASC c.t.	.	.	.	67 ± 5	.	.	.

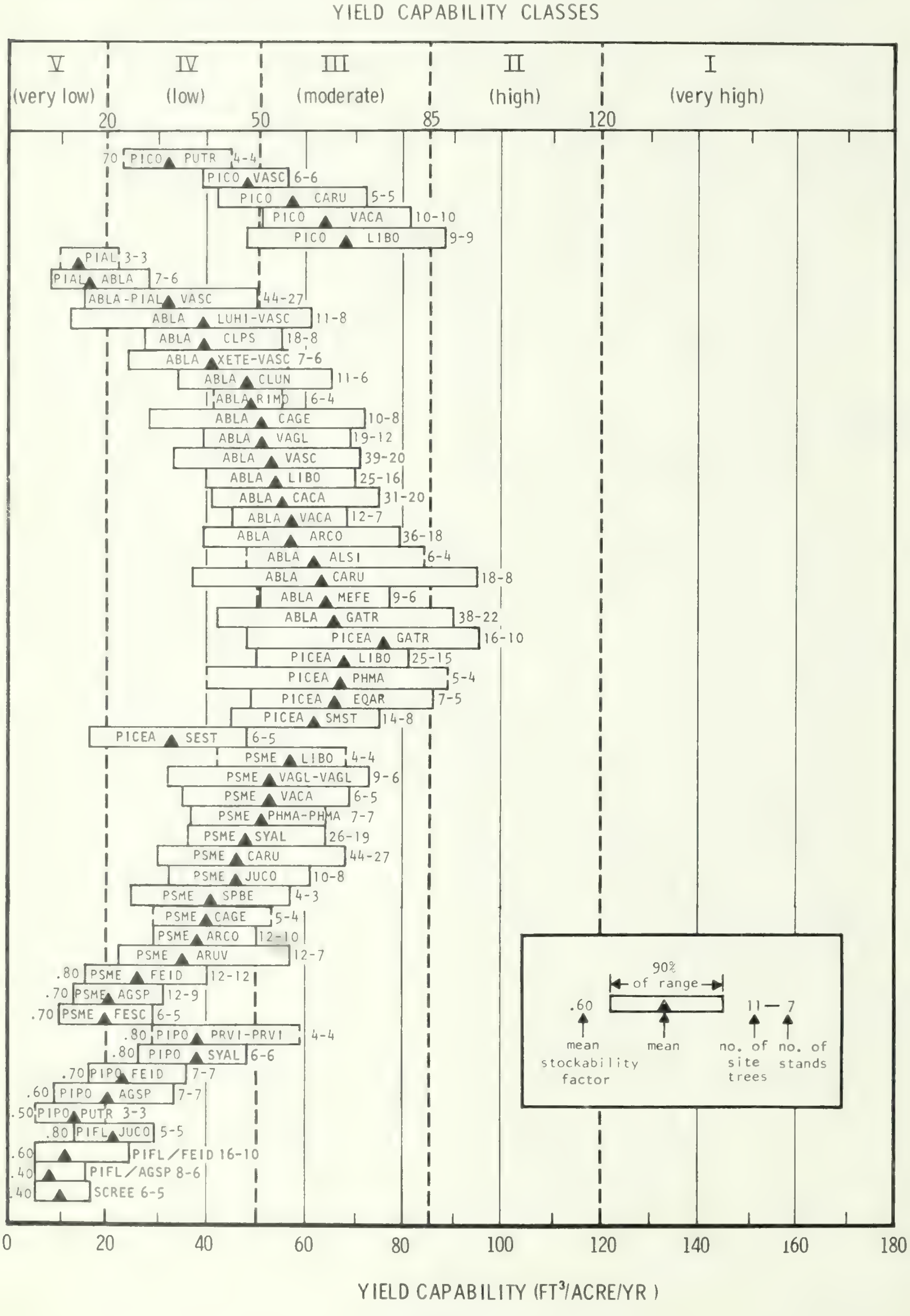
APPENDIX E-3

Estimated yield capabilities of West-side Montana habitat types based on site index data and stockability factors. (Kootenai, Flathead, Lolo, and Bitterroot National Forests)



APPENDIX E-4

Estimated yield capabilities of East-side Montana habitat types based on site index data and stockability factors. (Deerlodge, Beaverhead, Helena, Lewis and Clark, Gallatin, and Custer National Forests)



APPENDIX F

Montana habitat type field form (for 3 plots)

NAME

(CODE DESCRIPTION)

TOPOGRAPHY:	HORIZONTAL CONFIGURATION:	CANOPY COVERAGE CLASS:	
1-Ridge	1-Convex (dry)	0=Absent	3=25 to 50%
2-Upper slope	2-Straight	T=Rare to 1%	4=50 to 75%
3-Mid slope	3-Concave (wet)	1=1 to 5%	5=75 to 95%
4-Lower slope	4-Undulating	2=5 to 25%	6=95 to 100%
5-Bench or flat			
6-Stream bottom			

NOTE: Rate trees (>4" dbh) and regen (0-4" dbh) separately (e.g., 4/2)

DATE			
Plot No.			
Location			
T, R, S			
Elevation			
Aspect			
Slope	%	%	%
Topography			
Configuration			

	TREES Scientific Name	Abbrev	Common Name	Canopy Coverage Class		
1.	Abies grandis	ABGR	grand fir	/	/	/
2.	Abies lasiocarpa	ABLA	subalpine fir	/	/	/
3.	Larix lyallii	LALY	alpine larch	/	/	/
4.	Larix occidentalis	LAOC	western larch	/	/	/
5.	Picea engelmannii	PIEN	Engelmann spruce	/	/	/
6.	Picea glauca	PIGL	white spruce	/	/	/
7.	Pinus albicaulis	PIAL	whitebark pine	/	/	/
8.	Pinus contorta	PICO	lodgepole pine	/	/	/
9.	Pinus flexilis	PIFL	limber pine	/	/	/
10.	Pinus monticola	PIMO	western white pine	/	/	/
11.	Pinus ponderosa	PIPO	ponderosa pine	/	/	/
12.	Pseudotsuga menziesii	PSME	Douglas-fir	/	/	/
13.	Thuja plicata	THPL	western redcedar	/	/	/
14.	Tsuga heterophylla	TSHE	western hemlock	/	/	/
15.	Tsuga mertensiana	TSME	mountain hemlock	/	/	/
	SHRUBS AND SUBSHRUBS					
1.	Alnus sinuata	ALSI	Sitka alder			
2.	Arctostaphylos uva-ursi	ARUV	kinnikinnick			
3.	Berberis repens	BERE	creeping Oregon grape			
4.	Cornus canadensis	COCA	bunchberry dogwood			
5.	Holodiscus discolor	HODI	ocean spray			
6.	Juniperus communis (+ horizontalis)	JUCO	common (+ creeping) juniper			
7.	Ledum glandulosum	LEGL	Labrador tea			
8.	Linnaea borealis	LIBO	twinflower			
9.	Menziesia ferruginea	MEFE	menziesia			
10.	Oplopanax horridum	OPHO	devil's club			
11.	Physocarpus malvaceus	PHMA	ninebark			
12.	Prunus virginiana	PRVI	chokecherry			
13.	Purshia tridentata	PUTR	bitterbrush			
14.	Ribes montigenum	RIMO	mountain gooseberry			
15.	Shepherdia canadensis	SHCA	buffaloberry			
16.	Spiraea betulifolia	SPBE	white spiraea			
17.	Symphoricarpos albus	SYAL	common snowberry			
18.	Symphoricarpos oreophilus	SYOR	mountain snowberry			
19.	Vaccinium caespitosum	VACA	dwarf huckleberry			
20.	Vaccinium globulare (+ membranaceum)	VAGL	blue huckleberry			
21.	Vaccinium scoparium (+ myrtillus)	VASC	grouse whortleberry			
	PERENNIAL GRAMINOIDS					
1.	Agropyron spicatum	AGSP	bluebunch wheatgrass			
2.	Andropogon spp.	AND	bluestem			
3.	Calamagrostis canadensis	CACA	bluejoint			
4.	Calamagrostis rubescens	CARU	pinegrass			
5.	Carex geyeri	CAGE	elk sedge			
6.	Festuca idahoensis	FEID	Idaho fescue			
7.	Festuca scabrella	FESC	rough fescue			
8.	Luzula hitchcockii (= glabrata)	LUHI	wood-rush			
	PERENNIAL FORBS AND FERNS					
1.	Actaea rubra	ACRU	baneberry			
2.	Antennaria racemosa	ANRA	woods pussytoes			
3.	Aralia nudicaulis	ARNU	wild sarsaparilla			
4.	Arnica cordifolia	ARCO	heartleaf arnica			
5.	Athyrium filix-femina	ATFI	lady fern			
6.	Balsamorhiza sagittata	BASA	arrowleaf balsamroot			
7.	Clematis pseudoalpina (+ tenuiloba)	CLPS	virgin's bower			
8.	Clintonia uniflora	CLUN	queencup beadlily			
9.	Equisetum arvense	EQAR	common horsetail			
10.	Equisetum spp.	EQU	horsetails & scouring rush			
11.	Galium triflorum	GATR	sweetscented bedstraw			
12.	Gymnocarpium dryopteris	GYDR	oak fern			
13.	Senecio streptanthifolius	SEST	cleft-leaf groundsel			
14.	Senecio triangularis	SETR	arrowleaf groundsel			
15.	Smilacina stellata	SMST	starry Solomon's seal			
16.	Streptopus amplexifolius	STAM	twisted stalk			
17.	Thalictrum occidentale	THOC	western meadowrue			
18.	Valeriana sitchensis	VASI	sitka valerian			
19.	Viola orbiculata	VIOR	round-leaved violet			
20.	Xerophyllum tenax	XETE	beargrass			
			SERIES			
			HABITAT TYPE			
			PHASE			

APPENDIX G--Glossary

The following terms are defined in relation to our specific usage in this report. These definitions should minimize misunderstanding resulting from the fact that technical specialists have various definitions for some of these terms. Hanson (1962) and Ford-Robertson (1971) were used as primary references.

Abundant. When relating to plant coverage in the habitat type key, any species having a canopy coverage of 25 percent or more in a stand.

Accidental. A species that is found rarely or at most occasionally as scattered individuals in a given habitat type.

Association. Climax plant (forest) community type.

Basal area. The area of the cross-section of a tree trunk 4.5 feet above the ground, usually expressed as the sum of tree basal areas in square feet per acre.

Bench, benchland. An area having flat or gently-sloping terrain (less than 15 percent slope), applied usually to the higher ground in a river valley.

Browse. Shrubby forage utilized especially by big game.

Canopy coverage. The area covered by the gross outline of an individual plant's foliage, or collectively covered by all individuals of a species within a stand or sample plot. Canopy coverage is expressed as a percentage of the total area in the plot, or as a canopy coverage class (for example, class #1 = 1 to 5 percent coverage).

Climax community. The culminating stage in plant (forest) succession for a given environment, that develops and perpetuates itself in the absence of disturbance.

Climax species. A species that is self-regenerating in the absence of disturbance with no evidence of replacement by other species.

Climax, types of ... in relation to environment (Polyclimax Concept).

Climatic climax. The climax that develops on "normal" (well-drained, medium-textured) soils and gently sloping topography.

Edaphic climax. A variation from the climatic climax caused by "abnormal" soil conditions.

Topographic climax. A variation from the climatic climax caused by topography that markedly influences microclimate.

Topo-edaphic climax. A variation from the climatic climax caused by the combination of topographic and edaphic effects. (Example: *Larix lyallii* stands occupying north-slope boulder piles.)

Common. When relating to plant coverage in the habitat type key, any species having a canopy coverage of 1 percent or more in a stand.

Community (plant community). An assembly of plants living together, reflecting no particular ecological status.

Constancy. The percentage of stands in a habitat type that contain a given species. (Appendix C-1 uses "constancy classes"--"1" = 5 to 15 percent, "2" = 15 to 25 percent, etc.)

d.b.h. (diameter at breast height). Tree-trunk diameter measured 4.5 feet above the ground.

Depauperate. Describing an unusually sparse coverage of undergrowth vegetation. This condition usually develops beneath an especially dense forest canopy, often on sites having a deep layer of duff.

Ecosystem. Any community of organisms along with its environment, forming an interacting system.

Ecotone. The boundary or transition zone between adjacent plant communities, often representing different habitat types.

Edaphic. Refers to soil.

Forb. An herbaceous plant that is not a graminoid.

Frequency. The percentage of quadrats (tiny plots) in a single sample stand that contain a given species, or more generally the degree of uniformity with which individuals of a species are distributed in a stand.

Graminoid. All grasses (*Gramineas*) and grasslike plants, including sedges (*Carex*) and rushes (*Juncus*).

Habitat type. An aggregation of all land areas potentially capable of producing similar plant communities at climax.

Indicator plant. A plant whose presence or abundance indicates the presence of certain environmental conditions--presence of a habitat type or phase.

Phase. A subdivision of an association and a habitat type representing minor differences in climax vegetation and environmental conditions, respectively.

Phenotype. A group of individuals distinguished on the basis of visible characteristics--in contrast to a "genotype" which is defined on the basis of genetic similarities.

Poorly represented. When relating to plant coverage in the habitat type key, any species that is absent or has a canopy coverage of less than 5 percent.

Riparian. Vegetation bordering watercourses, lakes, or swamps; it requires a high water table.

Scarce. When relating to plant coverage in the habitat type key, any species that is absent or has a canopy coverage of less than 1 percent.

Scree. Any slope covered with loose rock fragments. Forested scree (abbreviated SCREE) is a term for certain topo-edaphic climaxes that are described under OTHER VEGETATION TYPES in this report.

Seral. A species or community that is replaced by another species or community as succession progresses.

Series. A group of habitat types having the same climax tree species. For example the *Pinus flexilis* series contains the *PIFL/AGSP, PIFL/FEID,* and *PIFL/JUCO* h.t.s.

Site index. An index of timberland productivity based upon the height of specific trees at a certain reference age (usually 50 or 100 years).

Stand. A plant community that is relatively uniform in composition, structure, and habitat conditions; thus it may serve as a local example of a community type on a habitat type.

Stockability factor. An estimate of the stocking potential on a given site; for example a factor of 0.8 indicates that the site is capable of supporting only about 80 percent of "normal" stocking as indicated in yield tables.

Stocking. A general term for the number of trees (considering their size class) per acre.

Succession. The progressive changes in plant communities toward climax.

Union. One or more species having similar environmental amplitudes within a geographic area; thus their presence is indicative of certain microenvironmental conditions.

Well represented. When relating to plant coverage in the habitat type key, any species having a canopy coverage of greater than 5 percent.

Yield capability. The maximum mean annual increment attainable in a fully stocked natural stand, expressed in cubic feet per acre per year. (See a forest mensuration textbook for the distinction between "mean annual increment" and "periodic annual increment"; growth in a specific year, or period of years, is termed the latter.)

Pfister, Robert D., Bernard L. Kovalchik, Stephen F. Arno, and Richard C. Presby
1977. Forest habitat types of Montana. USDA For. Serv. Gen. Tech. Rep. INT-34, 174 p. Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.

A land-classification system based upon potential natural vegetation is presented for the forests of Montana. It is based on an intensive 4-year study and reconnaissance sampling of about 1,500 stands. A hierarchical classification of forest sites was developed using the habitat type concept. A total of 9 climax series, 64 habitat types, and 37 additional phases of habitat types are defined. A diagnostic key is provided for field identification of the types based on indicator species used in development of the classification.

KEYWORDS: forest vegetation; Montana; habitat types; plant communities; forest ecology; forest management

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Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

Billings, Montana
Boise, Idaho
Bozeman, Montana (in cooperation with Montana State University)
Logan, Utah (in cooperation with Utah State University)
Missoula, Montana (in cooperation with University of Montana)
Moscow, Idaho (in cooperation with the University of Idaho)
Provo, Utah (in cooperation with Brigham Young University)
Reno, Nevada (in cooperation with the University of Nevada)

CONTENTS OF POCKET ON

INSIDE BACK COVER

Figure 7.--Key to climax series, habitat types, and phases (4 pages)

Appendix C-2.--Presence list: numbers of sample stands where each species occurred, by habitat type and phase. (2 sheets)

Appendix F.--Montana habitat type field form. (1 page)

Examples of forest habitat types in Montana (1 sheet)

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B. Key to Pinus ponderosa Habitat Types

1. Prunus virginiana well represented; only in southeastern Montana	PINUS PONDEROSA/PRUNUS VIRGINIANA h.t (p. 34)
a. Shepherdia canadensis well represented	SHEPHERDIA CANADENSIS phase
b. Shepherdia poorly represented	PRUNUS VIRGINIANA phase
1. P. virginiana poorly represented	2
2. Symphoricarpos albus well represented	PINUS PONDEROSA/SYMPHORICARPOS ALBUS h.t.(p. 33)
a. Berberis repens common	BERBERIS REPENS phase
b. Berberis scarce	SYMPHORICARPOS ALBUS phase
2. S. albus poorly represented	3
3. Purshia tridentata well represented	PINUS PONDEROSA/PURSHIA TRIDENTATA h.t.(p. 32)
a. Festuca idahoensis well represented or F. scabrella common	FESTUCA IDAHOENSIS phase
b. F. idahoensis poorly represented and F. scabrella scarce	AGROPYRON SPICATUM phase
3. Purshia poorly represented	4
4. Festuca idahoensis well represented or F. scabrella common	PINUS PONDEROSA/FESTUCA IDAHOENSIS h.t.(p. 31)
a. Festuca scabrella common	FESTUCA SCABRELLA phase
b. F. scabrella scarce	FESTUCA IDAHOENSIS phase
4. F. idahoensis poorly represented and F. scabrella scarce	5
5. Agropyron spicatum well represented	PINUS PONDEROSA/AGROPYRON SPICATUM h.t.(p. 30)
5. A. spicatum poorly represented; Andropogon spp. well represented	PINUS PONDEROSA/ANDROPOGON h.t.(p. 30)

C. Key to Pseudotsuga menziesii Habitat Types

1. Vaccinium caespitosum present	PSEUDOTSUGA MENZIESII/VACCINIUM CAESPITOSUM h.t.(p. 39)
1. V. caespitosum absent	2
2. Physocarpus malvaceus or Holodiscus discolor well represented	PSEUDOTSUGA MENZIESII/PHYSOCARPUS MALVACEUS h.t.(p. 41)
a. Calamagrostis rubescens and/or Carex geyeri are the dominant undergrowth	CALAMAGROSTIS RUBESCENS phase
b. Physocarpus and/or Holodiscus dominate the undergrowth.	PHYSOCARPUS MALVACEUS phase
2. Physocarpus and Holodiscus poorly represented	3
3. Linnaea borealis common	PSEUDOTSUGA MENZIESII/LINNAEA BOREALIS h.t.(p. 44)
a. Symphoricarpos albus well represented	SYMPHORICARPOS ALBUS phase
b. Vaccinium globulare well represented	VACCINIUM GLOBULARE phase
c. Not as above	CALAMAGROSTIS RUBESCENS phase
3. Linnaea scarce	4
4. Vaccinium globulare or Xerophyllum tenax well represented	PSEUDOTSUGA MENZIESII/VACCINIUM GLOBULARE h.t.(p. 43)
a. Arctostaphylos uva-ursi and Pinus ponderosa common	ARCTOSTAPHYLOS UVA-URSI phase
b. Xerophyllum common	XEROPHYLLUM TENAX phase
c. Not as above	VACCINIUM GLOBULARE phase
4. Vaccinium globulare and Xerophyllum tenax poorly represented	5
5. Symphoricarpos albus well represented	PSEUDOTSUGA MENZIESII/SYMPHORICARPOS ALBUS h.t.(p. 45)
a. Bunchgrasses well represented in old-growth stands	AGROPYRON SPICATUM phase
b. Calamagrostis rubescens well represented	CALAMAGROSTIS RUBESCENS phase
c. Not as above	SYMPHORICARPOS ALBUS phase
5. S. albus poorly represented	6
6. Calamagrostis rubescens well represented	PSEUDOTSUGA MENZIESII/CALAMAGROSTIS RUBESCENS h.t.(p. 47)
a. Bunchgrasses well represented in old-growth stands	AGROPYRON SPICATUM phase
b. Arctostaphylos uva-ursi common; sites capable of supporting Pinus ponderosa and not too dry for Pinus contorta (or Larix occidentalis)	ARCTOSTAPHYLOS UVA-URSI phase
c. Pinus ponderosa common	PINUS PONDEROSA phase
d. Not as above	CALAMAGROSTIS RUBESCENS phase
6. C. rubescens poorly represented	7
7. Carex geyeri well represented	PSEUDOTSUGA MENZIESII/CAREX GEYERI h.t.(p. 51)
7. C. geyeri poorly represented	8
8. Arctostaphylos uva-ursi well represented and Pinus ponderosa present	PSEUDOTSUGA MENZIESII/ARCTOSTAPHYLOS UVA-URSI h.t.(p. 52)
8. Arctostaphylos poorly represented or stands above elevational limits of Pinus ponderosa	9
9. Juniperus communis (or J. horizontalis) dominates the undergrowth	PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t.(p. 53)
9. J. communis not the dominant undergrowth plant	10
10. Spiraea betulifolia well represented	PSEUDOTSUGA MENZIESII/SPIRAEA BETULIFOLIA h.t.(p. 52)
10. S. betulifolia poorly represented	11
11. Arnica cordifolia or Antennaria racemosa the dominant undergrowth	PSEUDOTSUGA MENZIESII/ARNICA CORDIFOLIA h.t.(p. 54)
11. A. cordifolia and A. racemosa not the dominant undergrowth	12
12. Festuca scabrella common	PSEUDOTSUGA MENZIESII/FESTUCA SCABRELLA h.t.(p. 38)
12. F. scabrella scarce	13
13. Symphoricarpos oreophilus well represented and Festuca idahoensis scarce	PSEUDOTSUGA MENZIESII/SYMPHORICARPOS OREOPHILUS h.t (p. 55)
13. Not as above	14
14. Festuca idahoensis common; Pinus ponderosa scarce	PSEUDOTSUGA MENZIESII/FESTUCA IDAHOENSIS h.t.(p. 38)
14. F. idahoensis usually scarce; Agropyron spicatum well represented; Pinus ponderosa usually common	PSEUDOTSUGA MENZIESII/AGROPYRON SPICATUM h.t.(p. 37)

Figure 7. -- Key to climax series, habitat types, and phases.

INSTRUCTIONS FOR USING THE KEYS

1. Use this key for stands with a mature tree canopy that are not severely disturbed by grazing, logging, forest fire, etc. (If the stand is severely disturbed or in an early successional stage, the habitat type can best be determined by extrapolating from the nearest mature stand occupying a similar site.)

2. Accurately identify and record canopy coverages for all indicator species (appendix F).

3. Check plot data in the field to verify that the plot is representative of the stand as a whole. If not, take another plot.

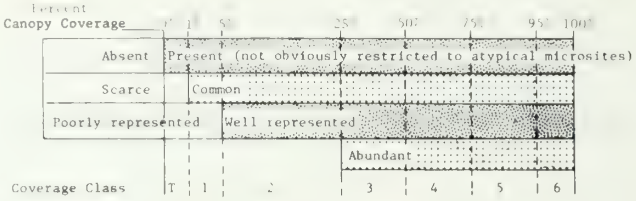
4. Identify the correct potential climax tree species in the SERIES key. (Generally, a tree species is considered reproducing successfully if 10 or more individuals per acre occupy or will occupy the site.)

5. Within the appropriate series, key to HABITAT TYPE by following the key literally. Determine PHASE by matching the stand conditions with the phase descriptions for the type. (The first phase description that fits the stand is the correct one.)

6. Use the definitions diagramed below for canopy coverage terms in the key. If you have difficulty deciding between types, refer to constancy and coverage data (appendix C-1) and the habitat type descriptions.

7. In stands where undergrowth is obviously depauperate (unusually sparse) because of dense shading or duff accumulations, adjust the above definitions to the next lower coverage class (e.g., well represented >1%, common >0%).

8. Remember, the key is NOT the classification! Validate the determination made using the key by checking the written description.



KEY TO CLIMAX SERIES

(DO NOT PROCEED UNTIL YOU HAVE READ THE INSTRUCTIONS!)

1. Habitats on steep slopes (30°)composed primarily of unstable fine rock; undergrowth sparse, poorly developed and quite variable. . . . SCREE (p. 121)
1. Habitats on sites with some soil development and stability; undergrowth rather well developed and somewhat uniform. 2

    2. Tsuga heterophylla present and reproducing successfully . . . . TSUGA HETEROPHYLLA SERIES (item G)
    2. Tsuga heterophylla not the indicated climax 3

3. Thuja plicata present and reproducing successfully. . . . THUJA PLICATA SERIES (item F)
3. Thuja plicata not the indicated climax. 4

    4. Abies grandis present and reproducing more successfully than Abies lasiocarpa. . . . . ABIES GRANDIS SERIES (item E)
    4. Abies grandis not the indicated climax. 5

5. Abies lasiocarpa, Tsuga mertensiana, or Larix lyallii present and reproducing successfully, or Pinus albicaulis the dominant tree . . . . . ABIES LASIOCARPA SERIES (item I)
5. Not as above. 6

    6. Picea present and reproducing successfully. . . . . PICEA SERIES (item D)
    6. Picea not the indicated climax. 7

7. Pinus flexilis a successfully reproducing dominant; often sharing that status with Pseudotsuga . . . . PINUS FLEXILIS SERIES (item A)
7. Pinus flexilis absent or clearly seral. 8

    8. Pseudotsuga menziesii present and reproducing successfully. . . . . . PSEUDOTSUGA MENZIESII SERIES (item C)
    8. Pseudotsuga menziesii not the indicated climax. 9

9. Pure Pinus contorta stands, with little evidence as to potential climax. . . . . PINUS CONTORTA SERIES (item H)
9. Pinus contorta absent; Pinus ponderosa the indicated climax . . . . PINUS PONDEROSA SERIES (item B)

A. Key to Pinus flexilis Habitat Types

1. Festuca idahoensis well represented or F. scabrella common. . . . . PINUS FLEXILIS/FESTUCA IDAHOENSIS h.t. (p. 25)
    a. Festuca scabrella common. . . . . FESTUCA SCABRELLA phase
    b. F. scabrella scarce . . . . FESTUCA IDAHOENSIS phase
1. F. idahoensis poorly represented and F. scabrella scarce. 2

    2. Agropyron spicatum well represented . . . . PINUS FLEXILIS/AGROPYRON SPICATUM h.t. (p. 24)
    2. A. spicatum poorly represented; Juniperus communis (or J. horizontalis) well represented . . . . .PINUS FLEXILIS/JUNIPERUS COMMUNIS h.t.(p. 26)

PUBLISHED AS PART OF "FOREST HABITAT TYPES OF MONTANA" - INT 1977

APPENDIX F

Montana habitat type field form (for 3 plots)

NAME

DATE

(CODE DESCRIPTION)

TOPOGRAPHY:	HORIZONTAL CONFIGURATION:	CANOPY COVERAGE CLASS:	
1-Ridge	1-Convex (dry)	0=Absent	3=25 to 50%
2-Upper slope	2-Straight	T=Rare to 1%	4=50 to 75%
3-Mid slope	3-Concave (wet)	1=1 to 5%	5=75 to 95%
4-Lower slope	4-Undulating	2=5 to 25%	6=95 to 100%
5-Bench or flat			
6-Stream bottom			

NOTE. Rate trees (>4" dbh) and regen (0-4" dbh) separately (e.g., 4/2)

Plot No.			
Location			
T, R, S			
Elevation			
Aspect			
Slope	%	%	%
Topography			
Configuration			

TREES Scientific Name	Abbrev	Common Name	Canopy Coverage Class		
1. Abies grandis	ABGR	grand fir	/	/	/
2. Abies lasiocarpa	ABLA	subalpine fir	/	/	/
3. Larix lyallii	LALY	alpine larch	/	/	/
4. Larix occidentalis	LAOC	western larch	/	/	/
5. Picea engelmannii	PIEN	Engelmann spruce	/	/	/
6. Picea glauca	PIGL	white spruce	/	/	/
7. Pinus albicaulis	PIAL	whitebark pine	/	/	/
8. Pinus contorta	PICO	lodgepole pine	/	/	/
9. Pinus flexilis	PIFL	limber pine	/	/	/
10. Pinus monticola	PIMO	western white pine	/	/	/
11. Pinus ponderosa	PIPO	ponderosa pine	/	/	/
12. Pseudotsuga menziesii	PSME	Douglas-fir	/	/	/
13. Thuja plicata	THPL	western redcedar	/	/	/
14. Tsuga heterophylla	TSHE	western hemlock	/	/	/
15. Tsuga mertensiana	TSME	mountain hemlock	/	/	/
SHRUBS AND SUBSHRUBS					
1. Alnus sinuata	ALSI	Sitka alder			
2. Arctostaphylos uva-ursi	ARUV	kinnikinnick			
3. Berberis repens	BERE	creeping Oregon grape			
4. Cornus canadensis	COCA	bunchberry dogwood			
5. Holodiscus discolor	HODI	ocean spray			
6. Juniperus communis (+ horizontalis)	JUCO	common (+ creeping) juniper			
7. Ledum glandulosum	LEGL	Labrador tea			
8. Linnaea borealis	LIBO	twinflower			
9. Menziesia ferruginea	MEFE	menziesia			
10. Oplopanax horridum	OPHO	devil's club			
11. Physocarpus malvaceus	PHMA	ninebark			
12. Prunus virginiana	PRVI	chokecherry			
13. Purshia tridentata	PUTR	bitterbrush			
14. Ribes montigenum	RIMO	mountain gooseberry			
15. Shepherdia canadensis	SHCA	buffaloberry			
16. Spiraea betulifolia	SPBE	white spiraea			
17. Symphoricarpos albus	SYAL	common snowberry			
18. Symphoricarpos oreophilus	SYOR	mountain snowberry			
19. Vaccinium caespitosum	VACA	dwarf huckleberry			
20. Vaccinium globulare (+ membranaceum)	VAGL	blue huckleberry			
21. Vaccinium scoparium (+ myrtillus)	VASC	grouse whortleberry			
PERENNIAL GRAMINOIDS					
1. Agropyron spicatum	AGSP	bluebunch wheatgrass			
2. Andropogon spp.	AND	bluestem			
3. Calamagrostis canadensis	CACA	bluejoint			
4. Calamagrostis rubescens	CARU	pinegrass			
5. Carex geyeri	CAGE	elk sedge			
6. Festuca idahoensis	FEID	Idaho fescue			
7. Festuca scabrella	FESC	rough fescue			
8. Luzula hitchcockii (= glabrata)	LUHI	wood-rush			
PERENNIAL FORBS AND FERNS					
1. Actaea rubra	ACRU	baneberry			
2. Antennaria racemosa	ANRA	woods pussytoes			
3. Aralia nudicaulis	ARNU	wild sarsaparilla			
4. Arnica cordifolia	ARCO	heartleaf arnica			
5. Athyrium filix-femina	ATFI	lady fern			
6. Balsamorhiza sagittata	BASA	arrowleaf balsamroot			
7. Clematis pseudoalpina (+ tenuiloba)	CLPS	virgin's bower			
8. Clintonia uniflora	CLUN	queencup beadlily			
9. Equisetum arvense	EQAR	common horsetail			
10. Equisetum spp.	EQU	horsetails & scouring rush			
11. Galium triflorum	GATR	sweetscented bedstraw			
12. Gymnocarpium dryopteris	GYDR	oak fern			
13. Senecio streptanthifolius	SEST	cleft-leaf groundsel			
14. Senecio triangularis	SETR	arrowleaf groundsel			
15. Smilacina stellata	SMST	starry Solomon's seal			
16. Streptopus amplexifolius	STAM	twisted stalk			
17. Thalictrum occidentale	THOC	western meadowrue			
18. Valeriana sitchensis	VASI	sitka valerian			
19. Viola orbiculata	VIOR	round-leaved violet			
20. Xerophyllum tenax	XETE	beargrass			
		SERIES			
		HABITAT TYPE			
		PHASE			

PUBLISHED AS PART OF "FOREST HABITAT TYPES OF MONTANA" - INT 1977

D. Key to Picea Habitat Types

1. Equisetum spp. abundant . . . . PICEA/EQUISETUM ARVENSE h.t.(p. 58)
   Equisetum spp. not abundant 2

  2. Clintonia uniflora, Cornus canadensis, or Aralia nudicaulis present (sites in northwestern Montana). . . . . PICEA/CLINTONIA UNIFLORA h.t.(p. 59)
      a. Vaccinium caespitosum present . . . . VACCINIUM CAESPITOSUM phase
      b. V. caespitosum absent . . . . CLINTONIA UNIFLORA phase
  2. Not as above 3

3. Physocarpus malvaceus well represented . . . . PICEA/PHYSOCARPUS MALVACEUS h.t.(p. 61)
3. Physocarpus poorly represented 4

  4. Two of these moist-site forbs present: Galium triflorum, Streptopus amplexifolius, Actaea rubra . . . . PICEA/GALIUM TRIFLORUM h.t.(p. 62)
  4. Not as above 5

5. Vaccinium caespitosum present . . . . PICEA/VACCINIUM CAESPITOSUM h.t.(p. 62)
5. V. caespitosum absent 6

  6. Linnaea borealis common . . . . PICEA/LINNAEA BOREALIS h.t.(p. 64)
  6. Linnaea scarce 7

7. Smilacina stellata or Thalictrum occidentale present . . . . PICEA/SMILACINA STELLATA h.t.(p. 65)
7. Not as above; Senecio streptanthifolius present; undergrowth depauperate . . . . PICEA/SENECIO STREPTANTHIFOLIUS h.t.(p. 63)
      a. Pseudotsuga menziesii common . . . . PSEUDOTSUGA MENZIESII phase
      b. Pseudotsuga scarce (stands above its elevational limits) . . . . PICEA phase

E. Key to Abies grandis Habitat Types

1. Clintonia uniflora present . . . . ABIES GRANDIS/CLINTONIA UNIFLORA h.t.(p. 67)
      a. Aralia nudicaulis, Gymnocarpium dryopteris, or Athyrium filix-femina common . . . . ARALIA NUDICAULIS phase
      b. Xerophyllum tenax well represented . . . . XEROPHYLLUM TENAX phase
      c. Not as above . . . . CLINTONIA UNIFLORA phase
1. Clintonia absent 2

  2. Linnaea borealis common . . . . ABIES GRANDIS/LINNAEA BOREALIS h.t.(p. 69)
      a. Xerophyllum tenax well represented . . . . XEROPHYLLUM TENAX phase
      b. Xerophyllum poorly represented . . . . LINNAEA BOREALIS phase
  2. Linnaea scarce; Xerophyllum common . . . . ABIES GRANDIS/XEROPHYLLUM TENAX h.t.(p. 69)

F. & G. Key to Thuja and Tsuga heterophylla Habitat Types

1. Oplopanax horridum well represented . . . . THUJA PLICATA/OPLOPANAX HORRIDUM h.t.(p. 73)
1. Oplopanax poorly represented 2

  2. Tsuga heterophylla present and reproducing successfully . . . . TSUGA HETEROPHYLLA/CLINTONIA UNIFLORA h.t.(p. 74)
      a. Aralia nudicaulis, Gymnocarpium dryopteris, or Athyrium filix-femina common . . . . ARALIA NUDICAULIS phase
      b. Not as above . . . . CLINTONIA UNIFLORA phase
  2. Tsuga heterophylla absent or not reproducing successfully . . . THUJA PLICATA/CLINTONIA UNIFLORA h.t.(p. 71)
      a. Aralia nudicaulis, Gymnocarpium dryopteris, or Athyrium filix-femina common . . . . ARALIA NUDICAULIS phase
      b. Menziesia ferruginea common . . . . MENZIESIA FERRUGINEA phase
      c. Not as above . . . . CLINTONIA UNIFLORA phase

H. Key for Pinus contorta Communities

1. Clintonia uniflora present . . . . ABIES LASIOCARPA/CLINTONIA UNIFLORA h.t.(p. 82)
1. Clintonia absent 2

  2. Two of these moist-site forbs present: Galium triflorum, Actaea rubra, Streptopus amplexifolius . . . . ABIES LASIOCARPA/GALIUM TRIFLORUM h.t.(p. 86)
  2. Not as above 3

3. Calamagrostis canadensis well represented . . . . ABIES LASIOCARPA/CALAMAGROSTIS CANADENSIS h.t.(p. 88)
3. C. canadensis poorly represented 4

  4. Vaccinium caespitosum present . . . . PINUS CONTORTA/VACCINIUM CAESPITOSUM comm. type(p. 118)
  4. V. caespitosum absent 5

5. Linnaea borealis common . . . . PINUS CONTORTA/LINNAEA BOREALIS comm. type(p. 119)
5. Linnaea scarce 6

  6. Xerophyllum tenax common . . . . ABIES LASIOCARPA/XEROPHYLLUM TENAX h.t.(p. 94)
  6. Xerophyllum scarce 7

7. Vaccinium globulare well represented . . . . ABIES LASIOCARPA/VACCINIUM GLOBULARE h.t.(p. 97)
7. V. globulare poorly represented 8

  8. Vaccinium scoparium well represented . . . . PINUS CONTORTA/VACCINIUM SCOPARIUM comm. type(p. 119)
  8. V. scoparium poorly represented 9

9. Calamagrostis rubescens well represented . . . . PINUS CONTORTA/CALAMAGROSTIS RUBESCENS comm. type(p. 120)
9. C. rubescens poorly represented 10

  10. Carex geyeri well represented . . . . ABIES LASIOCARPA/CAREX GEYERI h.t.(p. 105)
  10. C. geyeri poorly represented 11

11. Juniperus communis (or J. horizontalis) the major undergrowth . . PSEUDOTSUGA MENZIESII/JUNIPERUS COMMUNIS h.t.(p. 53)
11. Not as above; Purshia tridentata present . . . . PINUS CONTORTA/PURSHIA TRIDENTATA h.t.(p. 117)

NATIONAL FOREST SYSTEM
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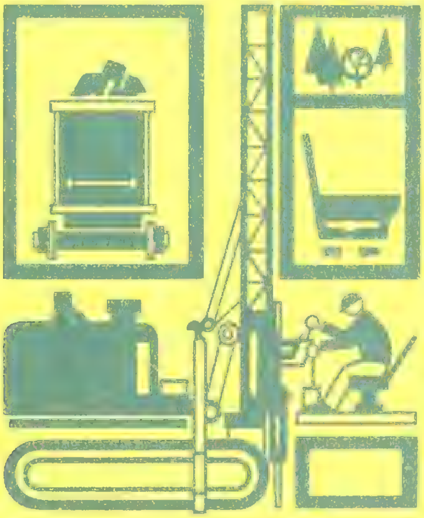
FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE

ANATOMY OF A MINE FROM PROSPECT TO PRODUCTION

SEP 8 1977



SURFACE ENVIRONMENT & MINING
SEAM
USDA FOREST SERVICE PROGRAM

USDA Forest Service
General Technical Report INT-35

INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

SURFACE ENVIRONMENT & MINING

SEAM

USDA FOREST SERVICE PROGRAM

This publication was produced with funding by the SEAM program. SEAM, an acronym for surface environment and mining, is a Forest Service program to research, develop, and apply technology that will help maintain a quality environment and other surface values while also recognizing the need to help meet the Nation's demands for minerals. SEAM is a partnership with land managers, planners, the mining industry, and all levels of Government.

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June 1977

ANATOMY OF A MINE FROM PROSPECT TO PRODUCTION

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
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ABSTRACT

Reviews mining laws and regulations and their application to mining in western States. Describes prospecting, exploration, mine development and operation, and reclamation factors.

Use of trade or firm names is for reader information only, and does not constitute endorsement by the U.S. Department of Agriculture of any commercial product or service.

CONTENTS

Page

FOREWORD ii

INTRODUCTION 1

MINING LAW 3

- Federal Laws 3
  - Claim Location 4
  - Lode vs. Placer Claims 5
  - Extralateral Rights 5
  - Tunnel Sites 5
  - Mill Sites 6
  - Claim Procedures 6
- Pursuit of Discovery 7
- Protection Prior to Discovery 8
- Discovery 9
- Locatable Minerals 9
- Leasable Minerals 10
- Salable Minerals 10
- Private Property 11
- State Laws 11
- Assessment Requirements 12
- Adverse Proceedings 13
- Rights of Claimants 15
- Multiple Surface Use Act of 1955 16
- Occupancy 16
- Trespass Limitations 17
- Federal and State Safety Requirements 18
- Environmental Regulations 18
- Forest Service Regulations 18

PROSPECTING 21

- The Conventional Prospector 22
- Amateur Prospectors 23
- Regional Mineral Exploration 23
- Exploration Concepts 24
- Preliminary Evaluation of Exploration Results 25

EXPLORATION 26

- Planning 27
  - Personnel 27
  - Access 27
  - Occupancy 27
  - Communications 28
  - Property Adjustments 28
  - Contact With Federal Agencies 28
- Geological Exploration Methods 28
  - Criteria for Ore Recognition 29
- Geochemical Exploration Methods 32
  - Reconnaissance Geochemistry 32
  - Rocks 32
  - Soils 33
  - Vegetation 35
- Geophysical Exploration Methods 35
  - Gravity 35
  - Seismic 35
  - Magnetic 35
  - Electromagnetic 36
  - Electrical 36
  - Radiometric 37
  - Remote Sensing 37
- Restudy of Old Mining Districts 38
- Trenches, Pits, Overburden Drilling 39
- Exploration Drilling 40
  - Hand Drilling 41
  - Percussion Drilling 41
  - Rotary Drilling 41
  - Diamond Drilling 42
- Underground Exploration 43
- Bulk Sampling 45
- Pilot Testing 46
- Feasibility Studies 46

DEVELOPMENT 47

- Drilling Large Deposits 48
- Drilling Small Deposits 48
- Development Shafts and Adits 49
- Blocking Out Ore Underground 49
  - Proven (Measured) Ore 49
  - Probable (Indicated) Ore 50
  - Possible (Inferred) Ore 50
- Access 50
- Power 51
- Communications 51
- Site Preparation 52
  - Mine 52
  - Mill 53
  - Townsite 53
- Postponement of Production 53

PRODUCTION 55

- Underground Mining Methods 55
  - Open Stoping 55
  - Shrinkage Stoping 55
  - Cut and Fill Stoping 56
  - Square-Set Stoping 57
  - Block Caving 57
- Surface Mining Methods 59
  - Placer Mining 59
  - Glory Holing 60
  - Open Pit Mining 61
  - Leaching Methods 62
- Ore Dressing 63
  - Crushing and Concentration 63
  - Extractive Metallurgy 64
- Wastes 65
  - Mine Wastes 65
  - Mill Wastes 66
  - Miscellaneous Junk 67
- Roads 67

RECLAMATION 68

FOREWORD

"Anatomy of a mine" was first prepared in looseleaf form as an aid to Forest Service land managers and other administrators with mineral area responsibilities in summarizing legislation affecting mining, defining terms used in the mining industry, and discussing basic concepts of mineral explorations, development, and operations in the West. The goal then as now, was to foster understanding and communication so needs for minerals and forest and range land surface values can be better coordinated to the benefit of all.

The 1975 guide was written primarily by private mining consultants, with coordination by William L. Johnson, Director, Minerals and Energy Staff, Intermountain Region, Forest Service. It quickly became very popular with land managers in many State and Federal agencies. Planners, environmentalists, and mining industry personnel sought copies. Many individuals urged that the information be provided in a generally available form. Thus, through the SEAM program, this publication was produced. It faithfully retains technical information included in the looseleaf version although revisions have been made in some parts of the presentation.

The support and encouragement of many individuals and organizations who contributed time in reviewing material for "Anatomy of a mine" is gratefully acknowledged. We hope that the publication makes a contribution to better understanding among land managers, planners, environmental groups, the public, and the mining industry.

Kenneth C. Scholz

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Program Manager
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INTRODUCTION

Western North America produces more metal and mineral products today than any other region of similar size in the world. Beginning with the forty-niner's discovery of gold, there has been one surge of mining activity after another. Silver in the Civil War era, copper at the turn of the century, potash, tungsten, phosphate, uranium, beryllium, to name but a few, have gained importance in turn as demand for metal and mineral products increased and new advances in technology were made.

When contemplating the present mineral production of the western United States, it is difficult to imagine how undeveloped much of the region must have appeared to the early explorers. The natives had in their possession only a few trinkets of gold, silver, and copper, and seemed to have little interest in, or knowledge of, minerals. The discovery of placer gold at Sutter's Mill at Coloma, California, in January of 1848 was the first of many events that revealed the importance of the rich mineral resources of the West. The series of major new mineral discoveries since the California gold rush seems paced almost as if the region were some sort of gigantic mineral warehouse stocked with new commodities for use as they become needed.

Long gone are the days when mineral exploration consisted of probing outcrops of bold gold and silver veins. The list of minerals required by industry today includes a majority of elements on the chemist's periodic chart, and the variety of ore deposits in which they occur is so great that no one individual could possibly be competent to prospect for them all. No government specialist, academic authority, or corporate expert is able to recognize the surface expression of all ore types under all conditions.

The era of the legendary mining engineer, who could go anywhere in the world and briskly size up the ore potential of any kind of mineral property, passed during World War I. The method of the mining engineer was to examine and sample the partially developed ore deposits found by early gold and silver prospectors, to determine if other metals might be present, low grade ores might be profitably mined by mechanized methods and treated by one of the efficient new metallurgical processes, or the property incorporated into a complex of mines, all shipping to a large, efficient, centralized smelter.

The modern explorationist goes back into areas investigated by the early prospectors and mining engineers, using new concepts of ore localization and techniques of search for mineral deposits that would have been of no interest to his predecessors. In the early years of mining, there was no market for most of the metals mined today. Transportation was inadequate, mechanized equipment and technology for development and treatment of the ores were lacking, and major capital was not available for investment in large mine developments and surface plants.

The series of recent major discoveries of previously unknown deposits of such materials as uranium, beryllium, potash, and gold makes it very clear that the long-term prediction of future mineral discoveries is a most hazardous occupation. It is not possible to determine that an area is lacking in mineral potential when the concept of the ore deposit containing it, the method of exploring for it, means of treatment, perhaps even the very use of it are totally unknown today. Therefore, the mineral explorationist views public land as a reserve of potential mineral resources in the very broadest sense. He sees his task as the efficient future exploration and discovery of ore deposits of sufficient number, size, and quality to be competitively developed. In his view, the ultimate logical extension of the idea that the Nation should withdraw certain tracts of public land for specific limited uses would require the reservation of extensive areas for exploration and and development of mineral resources.

Mineral values per acre may be immense in any given mineralized area. These values, whether known or potential, should be considered carefully in land use planning, particularly if withdrawals from mineral exploration and development are contemplated.

People within the mining industry have come to view with skepticism any suggestion for temporary withdrawal of mineral entry in a given area,where it is proposed that the land might later be opened to mining if the need becomes great enough. They reason that the lead time required to find, explore, and develop a prospect into a producing mine is such that the only way to be sure of future mining operations is to allow normal prospecting, exploration, and development over the widest possible area.When poorly planned, hurried work is done in response to crisis. This results in expensive exploration which is often not successful in developing significant new mineral resources. Also, great damage to the surface environment may result.

Only a very small percentage of prospects develop into producing mines; authoritative estimates are in the range of 1 in 5,000 to 1 in 10,000. The mineralized portions of the earth's crust are at fixed localities, and it is not possible to move the economic concentration of mineral to a location where mining might conflict less with other interests.

Mining industry leaders believe that if the search for minerals continues over broad areas, adequate new mineral resources can be found and developed. If mineral exploration is severely restricted, confined to much smaller areas, or if unreasonable burdens are placed on mining itself making investment unattractive, they feel that the number of new mineral finds will dwindle, perhaps to the point of major damage to the economy and the ability of the United States to provide for itself.

As an example of the unpredictable course of mineral development, 25 years ago Government authorities were seriously concerned because the United States lacked uranium ore, and the country's ability to defend itself and meet long-term energy needs was in question. Incentives were offered for uranium production, and major discoveries such as the Mi Vida deposit in Utah by independent geologist Charles Steen motivated others, so that within 10 years the Nation had developed the largest, richest uranium ore reserves in the world. Uranium mining has grown to the point of being second only to copper in economic importance in metal mining west of the Rocky Mountains.

There will be more pressure on public lands to produce minerals in the years to come. Many partially developed nations are beginning to look to their own future needs, and are no longer a source of cheap, easily available, high quality mineral raw materials. Established mineral-producing countries are becoming ever more nationalistic, and several have recently revised mining laws and imposed new taxes upon mining operations that have slowed or stopped mineral exploration. Capital formerly invested in exploration in such areas is now being directed to more politically favorable regions such as the western United States.

The increase in domestic demand for minerals progresses at an astonishing rate. More metal and mineral products have been used in the United States since World War II than were used in the entire previous history of the world, and demand increases each year. The sale of metal, minerals, and competitive products manufactured from them continue to increase in importance as a source of United States income overseas.

Society unquestionably derives major benefits from mineral production. To emphasize one commodity, the present major mining activity in the West centers upon the copper mines of Arizona, New Mexico, Utah, Nevada, and Montana. Without these mines, copper could not be produced in large quantities and at low cost, allowing its general use in mass production of electrical power, transportation, and other conveniences enjoyed by everyone today. Similar benefits could be cited in the case of other minerals such as lead, zinc, silver, gold, iron, coal, tungsten, and uranium. A healthy mining industry is important to the economy of the United States. The future need for minerals cannot be expected to diminish unless there is a major turn downward in the standard of living presently enjoyed in the United States. There is no doubt that the potential for future disovery of major new mineral resources exists on public land.

Some mining people and resource managers think that the present mining laws of the United States may soon be changed or modified. However, it should be noted that none of the laws considered by Congress in recent years contemplate closure of public land to mining. Mining has always been an authorized use of most National Forest land in the West. The language of the original legislation creating and authorizing the National Forests set forth the rights of a mineral locator as essentially the same as those of a person who locates a claim on other public land. The rights of the mineral claimant to explore and develop a valid claim on public lands open to mineral entry are clearly recognized.

MINING LAW

The body of mining law that authorizes and controls prospecting, claim procedures, leasing, development, and extraction of minerals on public lands includes Federal and State laws, regulations issued by administering agencies based upon those laws, and court decisions that have established precedents for settling disputes. Rules established by organized mining districts, envisioned as important in early Federal law, have little significance today. The organized districts have been gradually eliminated in most western States.

Federal Laws

Acquisition of mining claims on public land is a right granted by the United States Mining Law of 1872. This law, passed by Congress on May 10, 1872, continued a policy of opening mineral lands to exploration. The United States Mining Law of 1872 expresses the general system of acquiring mining claims that was formed in California and Nevada between 1848 and 1866. Until 1866 there was a Federal policy of benign neglect with the mineral claim system in use in the West.

A cornerstone of the early California Mining Law was that the discoverer obtained the right to his discovery. The early day custom was that a claim did not become property until mineral was discovered and perfected by development. This was the pattern for later law.

An 1866 mining law confirmed existing mining claims and contained the declaration that the minerals on public land were open to exploration by all citizens of the United States. The locator was given legal protection for his claim, and a system was devised by which a lode locator might acquire title by patenting. In 1870 the Placer Act amended the 1866 law to provide a method of patenting placer claims. These several acts facilitated the development of mineral resources of the western States and territories.

In 1872 the Acts of 1866 and 1870 were repassed by Congress as a single statute entitled the United States Mining Law of 1872. The acquisition of mining rights on large amounts of public land in the West is, for the most part, still governed by this law. The principal exceptions are the Mineral Leasing Act of 1920, which made certain nonmetalliferous minerals exclusively leasable and not open to acquisition by claim staking, the Materials Act of 1947 that defined a group of salable minerals; the Multiple Mineral Use Act of 1954 that provided for multiple mineral development of the same tracts of public lands; the Multiple Surface Use Mining Act of July 23, 1955, that withdrew common varieties from mineral entry; and a section of the Federal Land Policy and Management Act of 1976 that redefines claim recording procedures and provides for abandonment if the procedures are not followed.

Claim Location

The principal provisions of the 1872 statute are:

1. After discovery of a lode or vein, a mining claim may be located on a plot of land not exceeding 1,500 feet in length along the lode or vein and 300 feet on each side of the middle of such vein at the surface (fig. 1). Local mining district rules or State laws may limit the width of such claims to not less than 25 feet on each side of the middle of the vein at the surface. Surface end lines must be parallel.
2. Upon completing the lode location, the locator has the exclusive right of possession and enjoyment of all (a) surface included within the lines of the location for mining purposes; and (b) all veins, lodes, or ledges throughout their entire depth if the top or apex lies inside of the surface lines extended downward vertically, even though such veins may extend outside the vertical side lines of the surface location.
3. Placer claims located by a single individual and based upon a single discovery are limited to 20 acres. An association of individuals may locate up to 160 acres on each discovery.
4. Both placer and lode locators are required to perform $100 worth of development work per claim annually in order to hold their claims against subsequent locators.
5. There is provision for acquiring 5-acre claims of nonmineral land for mill site purposes.

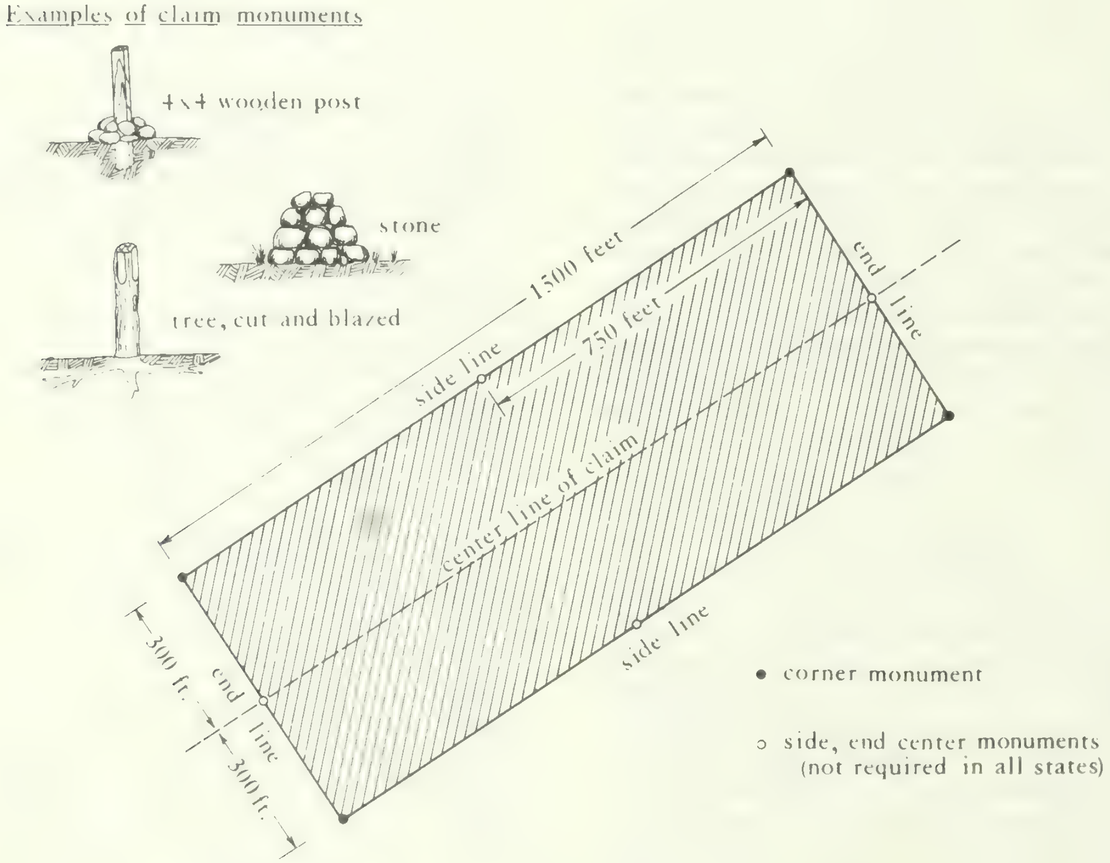


Figure 1.--Lode mining claim.

6. The section commonly referred to as the Tunnel Site Act gives an individual the right to prospect a maximum of 3,000 feet into a hillside, acquiring a prior right to all theretofore unknown veins and lodes cut by the tunnel; however, no surface rights are attached.

The United States Mining Law of 1872 does not sanction the disposal or use of public lands for purposes unrelated to mining.

Lode vs. Placer Claims

The mining location laws authorize two main types of claims--lode and placer--depending on the character of the deposit. Lode claims are staked on veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits. Placer claims are staked on all forms of deposit, excepting veins of quartz, or other rock in place.

The locator must decide into which category his deposit falls and stake a lode or placer claim as appropriate.

In the United States Mining Law of 1872, Congress drew a distinction between the traditional gold placer composed of alluvial material along streambeds and the vein or lode found in solid rock. In many modern cases the choice is difficult as many deposits do not clearly fall into either category.

A lode is frequently considered as a zone or belt of mineralized rock clearly separated from neighboring nonmineralized rock.

Placers are superficial deposits washed down from a vein or lode occupying the beds of ancient rivers, or deposits of valuable minerals found in particles of alluvium in beds of active streams.

These definitions emphasize the present form of the deposit more than its origin, so that a deposit bounded on either side by rock in place is likely to be considered a lode. If the ore is on top of the ground and has no cover except a thin veneer of soil, it is likely to be a placer. In the case of a dispute the courts tend to find in favor of the first locator.

A placer claim can be no larger than 20 acres for an individual, with associations of up to eight persons locating multiple claims of 20 acres per person up to 160 acres. A placer location does not establish rights to any lodes within its boundaries. Placer locations must conform as nearly as practicable to rectangular legal subdivisions. All of the persons in an association must be active participants in the venture. The rights of a "dummy locator" may be invalid, if he fails to actively assert the rights of a principal in the location. Corporations are considered to be a single person. There is no limit to the number of placer claims that may be located by an individual or association.

Extralateral Rights

The locator of a valid lode mining claim acquires the right to mine all the veins and ledges throughout their entire depth, the tops or apexes of which lie inside of the claim surface lines (fig. 2). Such veins or ledges may depart from a perpendicular in their course downward so as to extend outside vertical, downward extensions of the sidelines of the claim. Rights of the claim holder to mine the deposits after they leave the vertical claim lines underground are known as his extralateral rights.

Extralateral rights apply only to lode claims with parallel end lines and usually do not extend under adjacent private land. Lawsuits over extralateral rights were very common at one time, but today such disputes usually are settled privately.

Tunnel Sites

The law provides for tunnel sites where a horizontal excavation (adit) is made to discover lodes and veins not appearing at the surface. The owners of such tunnels gain the right of possession of any previously unknown veins or lodes discovered along the 3,000-foot distance between the portal and face of the tunnel.

A tunnel site conveys no surface rights and the right of possession of a vein discovered in a tunnel cannot be maintained unless the owner makes a lode location of the vein on the surface. Discontinuing work for 6 months constitutes abandonment of a tunnel site.

A monument must be placed at the portal of the tunnel naming the locator, stating the proposed direction of the tunnel, its height and width, and the course and distance from the portal to a permanent object in the vicinity. The boundary lines of the tunnel site must be established by stakes placed along the 3,000-foot length of the tunnel line. Tunnel sites are uncommon today.

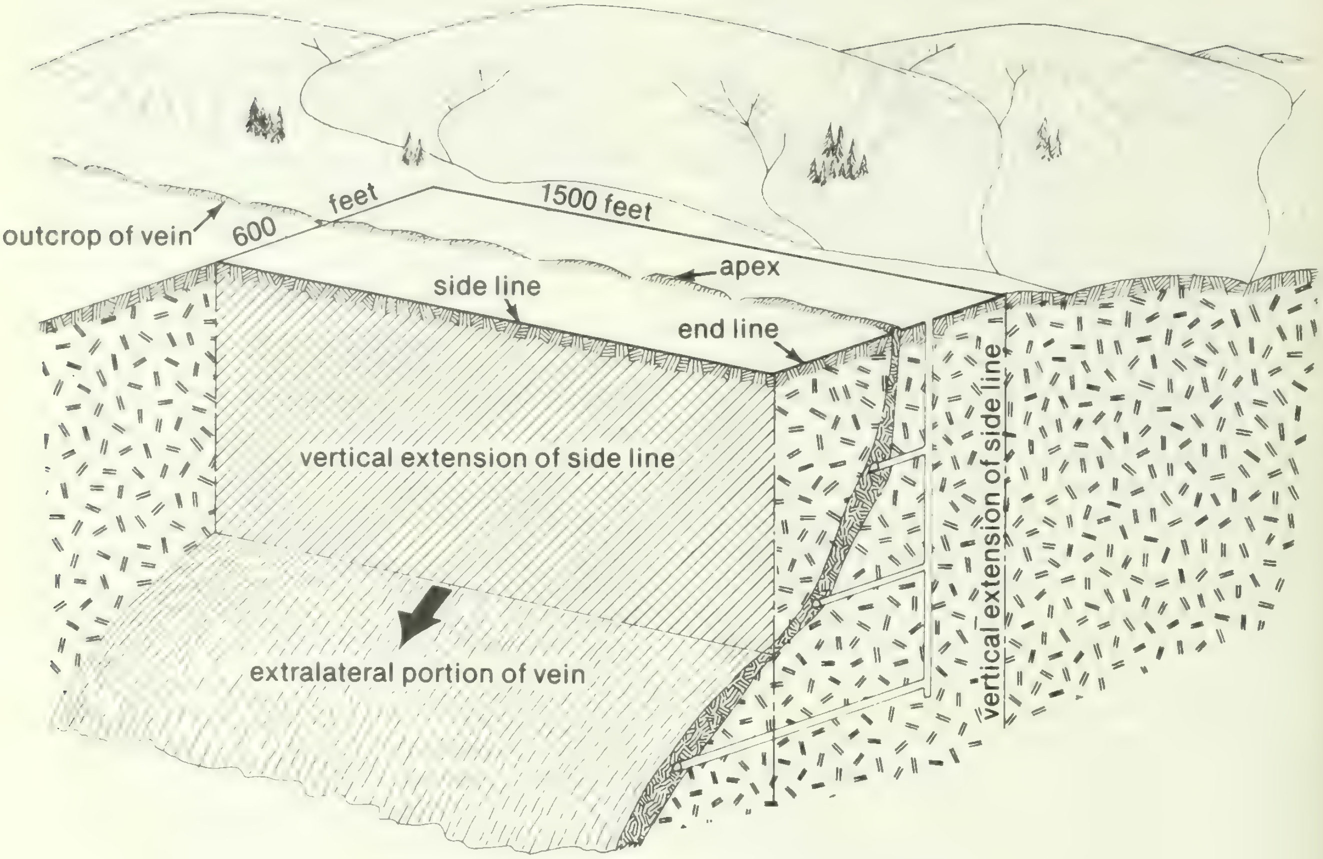

outcrop of vein
600 feet
1500 feet
apex
side line
end line
vertical extension of side line
extralateral portion of vein
vertical extension of side line

Figure 2.--Extralateral rights of a lode mining claim.

Mill Sites

A 5-acre plot of nonmineral land may be staked as a mill site. The land need not be contiguous to the claim that will produce the ore for the mill. Mill sites are monumented in the same manner as lode claims. No assessment work is required; but the mill site must be used for mining and milling purposes.

Claim Procedures

Under the United States Mining Law of 1872, land is claimed for minerals by distinctly marking the location on the ground so that its boundaries can be readily traced and making a record of the name or names of the locators, date of location, and a description of the claim or claims located by reference to some natural object or permanent monument that will identify the claim. In addition, State law requires the monumentation of claims by cornerposts, and in some cases, side and end centerposts. A copy of a location notice must be placed at the point of discovery and the location notice must be recorded with the recorder of the county in which the claim is situated. The Federal Land Policy and Management Act of 1976 requires that claim location documents also be filed with appropriate offices of the Bureau of Land Management.

Historically, mining claims have been marked or staked in a variety of ways. Claim corners and discovery points have been marked on the ground by rock monuments or cairns, trimmed and blazed trees, or iron posts embedded in soil, rock, or concrete. The most common markers, however, are 4-by-4 wood posts.

It is essential that the discovery be made and that the location monument and notice be on public land open to mineral entry, otherwise the entire claim is invalid. Portions of a younger lode location may overlap older locations and claim boundary monuments may be placed on land already claimed in order to square the claim or to take advantage of an extralateral right not held in apex by previous locators. The location monument is erected at some point along the centerline inside the claim. Less than 300 feet on either side of the centerline and less than 1,500 feet along the centerline may be claimed, but the claim can never exceed 600 by 1,500 feet in size.

All unappropriated Federal lands that have not been withdrawn from mineral entry are open to locations of mining claims. Appropriated public lands--those original public lands which are covered by an entry, including mining claims, patent certification, or other evidence of land disposal; or which are within a reservation, contain improvements constructed with Federal funds or are covered by certain classes of leases--are not open to mineral entry. Lands covered by mining claims validly maintained by another person are not subject to location.

Mining claims can be located in Alaska, Arkansas, Arizona, California, Colorado, Florida, Idaho, Louisiana, Mississippi, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming.

Land in National Monuments or National Parks, unless specifically authorized by law, Indian reservations, and acquired lands are not open for location. The claim locator must be a United States citizen or must have declared an intention to become a citizen. A domestic corporation is considered to be a citizen, regardless of the nationality of its stockholders. Employees of the Departments of the Interior and Agriculture are restricted in some ways from staking claims. A minor competent to acquire and hold interests in land under State law is a qualified locator.

The 1872 law specifically requires discovery of a valuable mineral deposit within the limits of the claim prior to locating a mining claim. Modern day mineral deposits are most often found at great depth and the actual discovery of mineral in place commonly occurs in a drill hole after considerable exploration work. The prospector or geologist finds geological,geophysical, or geochemical indications of mineralization long before the drilling phase of the program encounters the discovery of mineral in place.

Copies of the mining law and regulations in a form usable by prospectors, geologists, and Federal employees can be obtained in Title 43 of Code of Federal Regulations and in Title 30 of the U.S. Code Annotated. The pertinent portions of the 1872 law are published as a brochure by the U.S. Department of Interior, Bureau of Land Management, entitled Regulations Pertaining to Mining Claims Under the General Mining Laws of 1872, Multiple Use, and Special Disposal Provisions.

Pursuit of Discovery

In past years prospecting was limited to surface outcrops where discovery was easily made with limited equipment. Factors such as the ever-increasing demands for new mineral resources, the economic incentives to produce minerals, and the exhaustion of many known deposits make it necessary to intensify the search for new mineral deposits and to explore to considerable depths below the ground surface.

Science and technology have provided new methods, techniques, and instruments to aid in exploration. Mining companies have risked millions of dollars in mineral exploration and research. This has trained and provided experience for mineral explorationists in the art and science of ore finding. These advancements in ore finding capability open a new dimension not available to most prospectors. The old-fashioned prospector can find only what can be seen at the surface, and normally cannot afford the sophisticated methods used by the mining companies.

Exploratory work is necessary, in many instances, to perfect a discovery. The general mining laws are presently interpreted as extending an express invitation to enter upon the land and explore and, upon discovery, to claim by location with the promise of full reward. The prospector who enters upon vacant public land, peacefully and in good faith, is not a trespasser, but is a licensee or a tenant at will. This right to enter is a statutory right. A mineral discovery cannot be made without the right of entry and the time to explore.

Excavations are a necessary part of exploration for minerals. This necessity to excavate is not necessarily tantamount to removal and sale of the excavated minerals. The prospector seeks only to make a discovery by the use of such an excavation. In some cases it is necessary to sell extracted minerals to meet the marketability test of the valuable mineral deposit.

Discovery of a valuable mineral deposit is essential in creating valid rights to a claim and in obtaining a patent.

Because the discovery is the foundation of title to a mining claim, discovery must be pursued diligently by a bona fide claimant. Normally, to the locator, the sequence of events is immaterial. Discovery may precede the location of a claim or may follow the act of location; however, the actual time of discovery is important in that it establishes priority between claimants and with the Government when there is conflict. Priority of discovery gives priority of rights.

When two locators are in possession of overlapping claims before discovery, a race develops between the locators to make a discovery first and the first discoverer obtains priority of rights. The rights of a locator actually begin on the date of discovery of a valuable mineral deposit on a claim. This is true whether or not the required location work precedes or follows discovery. The need for secrecy in a new discovery can be easily seen in a case of probable competition from a rival capable of staking conflicting claims. There is no substitute for discovery on a mining claim. Length of time held and amount of money or effort consumed in working on a claim does not dispense with the need for discovery.

Where the issue of discovery is raised in a controversy with the Federal Government, the finding of small amounts of subeconomic mineral in sufficient quantity to encourage or induce further prospecting and exploration is not sufficient for a discovery. The actual mineral deposit must be disclosed and available for sampling by some means. Geological inference or opinion, no matter how strong, will not substitute for the actual exposure of mineral. Hope, belief, or expectation will not sustain a discovery.

There must be physical exposure of valuable mineral in surface outcroppings, pits, shafts, or drill hole samples to demonstrate the discovery. Drill core or cuttings will usually be accepted.

A lode discovery will not suffice for a placer claim nor will a pacer discovery suffice for a lode claim, and the discovery must be within the limits of the claim.

Protection Prior to Discovery

A person actively exploring a prospect desires protection against another locator on the land that he is exploring, for the time necessary to discover minerals in place.

The courts have recognized this problem and arrived at the doctrine of *pedis possessio* to provide protection to the modern bona fide prospector.

Under the *pedis possessio* doctrine, a claimant who has peacefully and in good faith staked claims in search of valuable minerals, may exclusively hold the claims while he is diligently working against others having no better right than he, so long as he retains a continuous exclusive occupancy and in good faith works toward making a discovery. During the period that the doctrine is operative in a particular situation, the claimant must be actively working toward making a discovery by digging or drilling. Making preparations for digging or drilling may not be sufficient unless the preparatory activity directly precedes the actual digging or drilling.

Whether or not a prospector, geologist, or mining company can successfully assert rights of *pedis possessio* may vary in each particular case. To claim the rights there must be actual physical possession of all the ground, diligent bona fide work directed toward making a discovery, and others must be excluded.

It is common exploration practice to locate a large block of claims over and around an area where it is suspected that deposits of valuable minerals may occur. The locator of such blocks is well advised to maintain exclusive possession and to pursue a discovery on each claim.

This possession or occupancy of the claims must be more than mere presence. Geophysical testing and geochemical work, unless followed immediately by drilling, may not be sufficient. However, the requirement of physical occupancy is usually satisfied by work in progress. The exclusion of others requires positive action. Rights are lost if an adverse claimant is permitted to enter the property peacefully. *Pedis possessio* protects against forcible entry. Thus it is necessary to deny entry to the intruding party.

If a confrontation occurs, and force is used by the entering party, the denial of entry need not be successful. The claimant or his agent simply yields to force, and then goes to his legal remedy. The claimant should make no statements indicating consent to trespass. In a land rush situation, a claim block should be patrolled to deny entry to other than authorized public officials. Proposed new changes in the Federal mining laws provide for exploration claims to cover a large area during the period prior to the discovery of valuable mineral in place. This could remedy some of the shortcomings of the 1872 Mining Law.

Discovery

What is a discovery? The Federal statutes that require discovery do not define the term, and the definition of discovery under the United States Mining Law of 1872 continues to be a subject of controversy. One basic standard for discovery has been the prudent-man test, which states that the requirements of discovery have been met when minerals have been found and there is evidence that a person of ordinary prudence would be justified in the further expenditure of labor and money, with a reasonable prospect of success in developing a valuable mine.

The test is not whether the individual claimant feels he is justified in further expenditure, but whether a hypothetical "reasonable" man would be so justified, and whether a profitable mining venture is probable.

In 1933, the U.S. Department of the Interior formulated the marketability test as a standard. The marketability test states that the mineral locator or applicant, to justify his possession of a location, must show by reason of accessibility, development, proximity to market, existence of present demand, and other factors that the deposit is of such value that it can be mined, removed, and disposed of at a profit.

The marketability test focuses on the economic value at the present time.

There continues to be a contest between the prudent man test and its extension -- the marketability test. Every locator should be prepared to defend his discovery under the standards of the marketability test. If a contest develops, the claim holder may be required to prove marketability in today's market.

In considering these definitions of discovery, certain rules must be kept in mind. The deposit discovered must be a valuable mineral deposit. This commonly means an assay or test of some kind must be made to determine the quantity and quality of metal or commodity in the discovery. The size of the deposit and the probable cost of production are also considered.

The immediate effect of a valid discovery is to remove the land upon which the discovery has been made from the unappropriated public lands.

The rules for determining what is a discovery of valuable mineral may vary according to the parties and interests involved. The tests are quite different in a contest between two adverse claimants than the tests used by the U.S. Government in a contest with a claimant. The United States, by appropriate methods, may question the validity of a claim at any time and, in the absence of a discovery, may terminate the prospector's possession of a particular claim by adjudication. The claimant, however may locate another claim on the general site, if he is acting in good faith.

Locatable Minerals

Whatever is recognized as a valuable mineral by standard authorities, whether metallic or other substance, when found on public land open to mineral entry in quality and quantity sufficient to render a claim valuable on account of the mineral content, is considered a locatable mineral under the United States Mining Law of 1872. Specifically excluded from location are the leasable minerals, common varieties, and salable minerals described in the next two sections.

Every valuable mineral deposit that is not excluded by special legislation is a locatable mineral. The United States Mining Law of 1872 specifically mentions rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits. As a general rule, all valuable metallic mineral deposits are locatable plus a large group of nonmetallic substances which have been determined to be locatable by either the Department of the Interior, a Federal or State court, or legislation by Congress. Some of the nonmetallic minerals in this group are borax, feldspar, fluorspar, and gypsum.

If a prospector, geologist, or land agency representative has any doubts about the locatable classification of a mineral deposit, he should consult a mineral expert on this point.

Leasable Minerals

The first major change in the United States Mining Law of 1872 came with the passage of the Mineral Leasing Act of 1920. Certain minerals were withdrawn from location and were placed under the Leasing Act which provides for their development through prospecting permits and leases. No permanent rights are acquired from the U.S. Government, only the right to explore for and mine the specific minerals covered by the lease or permit.

The 1920 Act, as amended from time to time, places the following minerals under the leasing law: oil, gas, coal, oilshale, sodium, potassium, phosphate, native asphalt, solid or semisolid bitumen, bituminous rock, oil-impregnated rock or sand, and sulfur in Louisiana and New Mexico.

In general, to hold a lease, the miner is required to pay an annual rental in advance, to pay a royalty to the Government on all material removed and sold, and to comply with any other provisions written into the lease.

The acquisition of mineral deposits by a lease from the Bureau of Land Management is very different from the location of a valid claim on a mineral discovery. Areas involved in leases are large compared to individual mining claims because of the nature of the occurrence of leasable minerals. Filing fees and yearly land rental fees are collected in advance, and bonds in varying amounts are required before the issuance of either a prospecting permit or a lease.

In areas in which leasable mineral deposits are not known to occur, minerals can be leased by a noncompetitive procedure. In areas in which leasable mineral deposits are known to occur in marketable quantities, leases are issued to the highest bidder, either by sealed bid or at public auction. Leases issued in this manner are termed competitive leases. Regulations pertaining to the leasing of minerals other than oil and gas can be obtained in a Bureau of Land Management Circular or in Title 43 of the Code of Federal Regulations.

Public lands that passed from Federal ownership through acts of Congress or disposal laws and were later reacquired by the United States are known as acquired lands. Minerals subject to location on other lands must be leased on acquired lands.

The royalty rates for each lease are set by the Geological Survey and may be obtained from their office. For all minerals in the same general area, royalties are usually the same. Royalties for the same minerals may be different in various areas of the United States.

The Multiple Mineral Use Act of 1954 allows land that is leased for one commodity to be claimed to cover minerals not in the leasable category. In some cases this can be important where locatable minerals are found in an oil and gas lease area.

Salable Minerals

The Materials Act of 1947, as amended, removes petrified wood, common varieties of sand, stone, gravel, pumice, pumicite, cinders, and some clay from location and leasing. These materials may be acquired by purchase only and are referred to as salable minerals.

Sales are handled through the agency administering the land upon the request of an interested party or upon the request of an authorized official. Sales are by competitive bidding if there is more than one interested party, otherwise a sale is negotiated by the authorized officer after the materials are appraised.

The sale of minerals does not limit the right of the U.S. Government to use the surface and to issue permits and licences that do not interfere with the purchaser's production of minerals. The land must be reclaimed as required by the sale contract or by law when mining is completed.

A mining claimant risks prosecution for trespass and may be liable for damages if he removes salable materials from an unpatented mining claim.

Private Property

It is not uncommon for minerals beneath private property to be owned by someone other than the surface owner or by the Government.

Parcels of land that passed from the public domain into private ownership prior to the Stock Raising Homestead Act of December 29, 1916, were classified as nonmineral and the minerals that might be under these lands passed to the fee owners of the surface. This 1916 Act eliminated any problems of mineral versus nonmineral lands by providing for the reservation to the United States of all minerals in every patent under this Act. Thus, most lands patented under the various homestead acts from the public domain after 1916 are open to mineral entry under the United States Mining Law of 1872.

There are many laws under which the original title to land could be obtained, and it is necessary to check the document in the land records to determine the law under which the title was granted.

Disposals under other laws both before and after the Stock Raising Homestead Act of 1916 often reserved minerals to the Government. The Secretary of the Interior has never issued regulations to dispose of these reserved minerals.

It is necessary for the miner to pay the private surface owner for damage to the surface caused by prospecting, mineral development, and mining. This is commonly done by arranging for a bond through the Bureau of Land Management as security for damage to the surface, or by entering into a contract with the surface owner.

Sections 5 and 6 of the Taylor Grazing Act of June 28, 1934, as amended, provided that the rights of the miner were not to be restricted in prospecting, locating, developing, mining, entering, or patenting under applicable laws any mineral deposits found on lands leased for grazing. The grazing lease holder cannot restrict proper and lawful ingress or egress for prospecting purposes.

Minerals that are owned in fee simple by the surface owner or that have been reserved in private ownership separately from the surface are not open for prospecting, development, or mining without permission from the owner. Normally, the mining company attempts to obtain a lease with option to purchase from the owner.

State Laws

The United States Mining Law of 1872 did not preempt the field, and State laws are permitted to elaborate on some aspects of mining law not covered specifically by the Federal act.

State statutes deal primarily with location procedures, some aspects of assessment requirements, and the time method for filing documents. Most western States require posting of the notice of location on the land, which is not required by Federal law. The information required on the notice varies from State to State, and contains substantially the same information as the recorded certificate.

Nearly all States require location work, although the Federal law does not. Although location work is intended to disclose the evidence of discovery, it may or may not result in a discovery. Location work is sometimes erroneously referred to as discovery work.

All States require corner monuments. End-center and side-center monuments may or may not be required and the size and character of these monuments varies from State to State.

All records of unpatented mining claims are kept in the county courthouse of the county in which the claim is located. Under provisions of the Federal Land Policy and Management Act of 1976, similar documents will have to be filed with appropriate Bureau of Land Management offices.

When the United States Mining Law of 1872 was passed, most western land was unsurveyed. In some western States there is still unsurveyed land. In many cases the descriptions of mining claims are so vague that they can properly be considered a floating claim block. For unscrupulous claimants this type of claim block may have the utilitarian value of being moved over any new discovery in the vicinity. The floating claim block can be moved anyplace that the claimant desires by moving the claim posts and thus predate claims made by the discoverer. It is normally possible to contest such action, but the claimant may hold out for a considerable cash payment for his nuisance value. Many attorneys will advise the major mining company to pay rather than fight, in order to get on with exploration.

State mining laws in some cases require a map filed with the county recorder and perhaps a payment as well in lieu of location work. In Nevada, the county uses the payment to compile a master claim map, thus eliminating floating claims. Any extra fee money provides an income to the county for general use.

Most mining legislation does not vary drastically from State to State; however, there is enough variation that an element of confusion and uncertainty pervades the State mining laws and a prospector or geologist must always carefully examine the law, particularly with reference to location and assessment procedures.

Assessment Requirements

The annual labor or improvements required by the United States Mining Law of 1872 on an unpatented claim is commonly referred to as assessment work. The general purpose of this work is to assure good faith and diligence and to prevent a claimant from holding claims without working the ground, thus preventing others from making entry.

The pertinent provisions of the United States Mining Law of 1872 require assessment work as follows:

> ...On each claim located after the 10th day of May, 1872, and until a patent has been issued therefore, not less than $100 worth of labor shall be performed or improvements made during each year...; but where such claims are held in common, such expenditure may be made upon any one claim; and upon a failure to comply with these conditions, the claim or mine upon which such failure occurred shall be open to relocation in the same manner as if no location of the same had ever been made, provided that the original locators, their heirs, assigns, or legal representatives have not resumed work upon the claim after failure and before such location.... The period within which the work required to be done annually on all unpatented mineral claims located since May 10, 1872, shall commence at 12 o'clock meridian on the 1st day of September succeeding the date of location of such claim....

By Act of February 11, 1875, the following provision was added to the United States Mining Law of 1872:

> ...Where a person or company has or may run a tunnel for the purposes of developing a lode or lodes, owned by said person or company, the money so expended in said tunnel shall be taken and considered as expended on said lode or lodes, whether located prior to or since May 10, 1872; and such person or company shall not be required to perform work on the surface of said lode or lodes in order to hold the same as required by this section....

The most recent Federal legislation was enacted on September 2, 1958, and provides:

> ...The term labor, as used in the third sentence of section 2324 of the Revised Statutes (30 U.S.C. 28), shall include, without being limited to, geological, geochemical and geophysical surveys conducted by qualified experts and verified by a detailed report filed in the county office in which the claim is located which sets forth fully (a) the location of the work performed in relation to the point of discovery and boundaries of the claim, (b) the nature, extent, and cost thereof, (c) the basic findings therefrom, and (d) the name, address, and professional background of the person or persons conducting the work. Such surveys, however, may not be applied as labor for more than two consecutive years or for more than a total of five years on any one mining claim, and each survey shall be nonrepetitive of any previous survey on the same claim....

The regulations as stated in Title 43 of the Code of Federal Regulations, provide that:

> (a) The term geological surveys means surveys on the ground for mineral deposits by the proper application of the principles and techniques of the science of geology as they relate to the search for and discovery of mineral deposits;
>
> (b) The term geochemical surveys means surveys on the ground for mineral deposits by the proper application of the principles

and techniques of the science of chemistry as they relate to the search for and discovery of mineral deposits;

(c) The term geophysical surveys means surveys on the ground for mineral deposits through the employment of generally recognized equipment and methods for measuring physical differences between rock types or discontinuities in geological formations; and

(d) The term qualified expert means an individual qualified by education or experience to conduct geological, geochemical or geophysical surveys, as the case may be.

In most States, filing of proof of labor in the county records is required by State law within a limited time period.

The question of what can qualify for assessment work is not always easy to answer. It is necessary to remember that it is $100 worth of labor and improvements. The work must have a value of $100, not necessarily cost $100. Geological, geochemical, and geophysical surveys, some road work, tunneling, digging pits, cuts or trenches, or excavations, and drilling which tends to develop the mineral deposit qualify as assessment work.The intent is to induce development of minerals and to avoid speculative holding of claims. Casual prospecting or surface sampling for the purpose of making a discovery will not serve as assessment work.

Over the years the courts have generally prescribed rules governing the character of the work and improvements that will satisfy the assessment work requirement. The court rulings have been lengthy and complex, but they can be summarized as follows: the labor and improvements, within the meaning of the statute, should be deemed to be done when the labor is performed or improvements made for the purpose of working, prospecting, or developing the mining ground embraced in the location, or for the purpose of facilitating the extraction or removal of ore.

Claims may be grouped for assessment work purposes. That is, work can be done on one or more claims rather than on each claim in a group, and the assessment work requirements can be met if the value of the work is sufficient. The claims must be contiguous, that is, overlap or share common sidelines, and there must be a community of interest if more than one claim owner is involved. There are no rules that completely cover the grouping of claims. The circumstances in each case can be important.

As a practical matter, many claim holders do little or no assessment work on their claims and file questionable proof of labor statements. In some circumstances this may constitute perjury.

If there is a contest over the performance of assessment work, the burden of proof concerning the performance generally is on the party contending that the required work was not done. As a general rule, in court cases where a second locator attempts to relocate the claim of the original locator who has allegedly failed to perform the required assessment work, most decisions tend to protect the original locator where it appears that he has acted in good faith. The courts generally do not substitute their judgement for that of the miner if the work tends to develop the claim and facilitate the extraction of ore.

The absence of an assessment work affidavit in the county records may encourage a new claimant interested in the ground to locate new claims. The failure by the original locator to file the proof of labor forms does not verify that the required annual work was not done. If the original locator can prove that the necessary assessment work was done, he retains rights of possession under Federal law.

To the prospector or independent geologist, traveling to numerous claim groups and performing assessment work can be an onerous and expensive task. Most mining companies with large claim holdings maintain a system of records in the company files and assign one man for part or all of the year to keep track of assessment work and see that it is properly recorded. The Government may under certain circumstances invalidate a claim where assessment work has not been performed.

Adverse Proceedings

The problems of adverse claimants can fall under two general categories:

1. A contest between two private citizens or companies over ownership of mining claims.

2. A legal action initiated by the U.S. Government against a mining claim held by a private citizen or corporate claimant.

In past years there was much litigation over extralateral rights, where a vein apexed (fig. 2) on one claim and extended down-dip off the claim. This type of litigation was commonly bitter and costly to settle. Extralateral rights litigation between two adverse claimants is now uncommon, as negotiated settlements are more satisfactory than drawnout expensive lawsuits.

Occasionally, two exploration groups may decide at approximately the same time to stake a large block of claims over a target area where exploration will be required to make a discovery. One group may begin staking claims first and the second group may stake from the other end of the area, possibly not knowing of the competitor's activity, and a "staking rush" is on when either or both of the parties discover the other's activities.

As they become aware of each other's activities, the doctrine of *pedis possessio* (see Protection Prior to Discovery section) will come into use. One group may attempt to deny peaceful intrusion onto its claims by the other group. An adverse claimant situation often exists between the two groups. The key to the situation now depends on who can make a discovery first, usually by drilling. Many complex legal problems may develop as the claimants race to be the first to make a discovery.

About this time, it is possible that a group of floating older claims in the district will be moved under the claims covering the new discovery area. There is also the possibility that placer claims will be staked by unscrupulous individuals over the discovery area in the hope that the major mining company will buy out the nuisance value of the placer claims rather than fight in court. Sometimes the mining company's counsel will mistakenly advise a payoff; each time this is done it only compounds future difficulties.

There may be circumstances where a group of claims will appear to be abandoned. A search of the county records fails to reveal an assessment affidavit for the immediate past assessment year ending at noon on September 1. Inspection of the ground reveals no recent physical work of the kind required for assessment. Under these circumstances, a new set of claims may be staked on what appears to be open ground. The new claimant does the required location work and begins exploration--pursuit of discovery--on the claim group.

If the former claimant has in fact abandoned the claims there will be no problems; however, if the former claimant had no intention of abandoning the ground there may be a legal contest over who has the best claim to the ground. If the original claimant has filed his proof of labor, the new claimant would have to prove that the assessment work had not been done. Not having filed the proof of labor, the original claimant now may be in the position of having to prove that he performed the required assessment work.

Claims staked for leasable or salable minerals are subject to adverse action by the U.S. Government. The claimant is in trespass and may end up paying for the minerals that have been illegally removed. It is possible to locate legal mineral claims covering the same ground where the U.S. Government has leased or sold the nonlocatable minerals. No title is obtained to the nonlocatable minerals and their production cannot be impeded by the locator.

Many cases of unauthorized occupancy have caused the Government to initiate an action to remove a home or cabin or to correct some other nonmineral use.

Some claimants locate claims on land that is not open for mineral entry. This is often done where the locator believes the claims to be in a different section of land than they actually are. This may be a surveying problem, or the claimant may have failed to make the necessary check of the land management agency records to determine the status of the land.

Congress has given the Department of the Interior adjudicative powers in matters relating to the mining laws. The most common action is a contest of claim validity conducted under the regulations of the U.S. Department of Interior. The Department of the Interior's authority in this area has been confirmed by the U.S. Supreme Court. The administering agency can initiate a complaint which will result in a contest through the Department of Interior under the Administrative Procedures Act for a variety of reasons, including lack of discovery. Necessary action may be initiated simultaneously in the Federal Courts to resolve urgent conflicts. After proceeding through the Department of the Interior regulations process, the contest may go to the U.S. District Court with appeals to the Circuit Court or Supreme Court. Where the contest is of great magnitude, considerable time, money, and effort can be expended in actions of this type.

At the time of application for patent, there is a 60-day period when adverse claims can be filed with the office where the patent application was initiated. An adverse claim may be brought by another claimant who can demonstrate a right to all or a portion of the claim being patented. There is also an opportunity for persons in the vicinity of a mining claim to protest that the patent applicant has not met the mining law requirements. Protests against a patent can be filed by the Forest Service at any time before patent for noncompliance with discovery or labor requirements.

Rights of Claimants

Under the United States Mining Law of 1872, the locator of a valid mining claim that has been perfected by the discovery of a presently marketable mineral deposit and by the performance of all the required acts of location acquires the exclusive right of possession and enjoyment of all of the locatable minerals within the boundaries of his location. He also acquires any appropriate extralateral rights along with the use of the surface compatible with the Multiple Surface Use Act of 1955.

Prior to the discovery of a presently marketable mineral deposit within the claims boundary, the claimant has a questionable title to the claim. Prediscovery rights can be held against an adverse claimant under the doctrine of *pedis possessio* by actively pursuing discovery and maintaining continuous exclusive occupancy. This doctrine provides only tenous prediscovery protection and it is not possible to generalize as to what action will satisfy the requirements in all cases; litigation my often result.

The claim locator has the right to prospect, develop the mineral potential, do assessment work, and perform other acts related to exploration that are not forbidden by law or regulation.

Where there are conflicting or overlapping claims, most rights are determined on the basis of priority of discovery, but subsurface rights are not necessarily so determined. Extralateral rights to a vein are based on apex considerations.

Valid, unpatented mining claims are real property in the full sense of the term, except as modified by multiple use legislation. When all requirements have been met, the locator has a valid, marketable title for mining purposes. As long as the locator complies with Federal and local laws and regulations in good faith, he has possessory title segregated from the public lands, although the paramount title remains in the U.S. Government until a patent is granted. This possessory title may be maintained indefinitely as long as the appropriate laws are complied with. This title does not include timber except as used for mining purposes on the claim, nor the right to nonmining use of the surface. Assessment work must be done on the claim in the amount of $100 per claim for each assessment year to maintain the possessory title. The assessment year begins at noon on September 1 of each year.

A claim locator who does not perform assessment work for a period may resume such work at any time, in the absence of the intervening rights of an adverse claimant on the ground. The original claim locator regains the same rights and title he obtained by locating the original claim, providing that he can demonstrate the existence of a valuable deposit of a locatable mineral.

The U.S. Government may initiate a contest using the Bureau of Land Management adverse claim procedures for cause affecting the legality of a mining claim. The procedure is set forth in the Federal statutes as supplemented by Department regulations.

In a mineral contest between the Government and a claimant the Government is required to present *prima facie* evidence (evidence sufficient to raise a presumption of fact or establish the fact in question unless rebutted) that the claim is invalid. The claimant has the right to retain expert assistance in defending his position and must show by a preponderance of evidence that his claim is valid.

In actual practice, the average claimant has not made a valid discovery prior to locating his claim. Many claimants mistakenly believe that compliance with State location laws fulfills the Federal requirement of discovery. It is common for a claimant to refer to having done the discovery work on a claim when in actual fact he has done the State-required location work.

Under the Multiple Surface Use Act of July 23, 1955, prior to the issuance of a patent the United States and its licensees have the right to use as much of the surface and surface resources as is necessary for access to adjacent land, providing that this use does not interfere with prospecting, mining, or processing. The claimant does not have the right to use an unpatented mining claim for purposes other than prospecting, mining, or processing operations and uses reasonably incident thereto. In the interpretation of what is "reasonably incident thereto," there are gray areas subject to various interpretations.

The claimant has the optional right to apply for a patent. The conditions that must be met prior to filing an application are: a valid discovery of a valuable mineral deposit, the performance of $500 worth of improvements which directly facilitate the development of the mineral deposit, and the preparation of survey plat and field notes by a Deputy U.S. Mineral Surveyor. If the patent application is successful, the claimant must pay for the land at the rate of $5 per acre for a lode claim and $2.50 per acre for a placer claim. After patent, the surface and minerals on the claim are private land subject to local property taxation, and the annual assessment work is no longer required.

Multiple Surface Use Act of 1955

Congress enacted the Multiple Surface Use Act in 1955 to curtail nonmining use of the surface of mining claims. Under the Act any mining claim located after July 23, 1955, shall not be used prior to the issuance of patent for any purposes other than prospecting, mining, or processing operations and uses reasonably incident thereto. The rights of the holder of a claim staked after July 23, 1955, and prior to patent are subject to the right of the United States to manage and dispose of the vegetative surface resources and to manage other surface resources, except the locatable mineral deposits on the claim.

The Act also provides that mining claims will be, prior to issuance of a patent, subject to the right of the Government to use so much of the surface as may be necessary for access to adjacent land. Any use of the surface of the mining claim by the Government must not endanger or materially interfere with prospecting, mining, or processing operations or uses reasonably incident thereto.

The holder of a valid mining claim is still authorized to cut and use timber from the claim for mining purposes.

The result of this legislation is that the owner of a mining claim is entitled to use the surface only as necessary for the mining operation, and the claims are subject to surface managment by the Federal Government until patented.

Occupancy

The mining laws permit a claimant to make reasonable use of the claim surface area prior to a patent being granted, so long as this use is connected with mining. The mining laws do not permit the use of an unpatented mining claim for land on which to build a home or cabin. There have been many cases where persons unfamiliar with the mining laws have built homes or cabins on claims staked with this idea in mind, or purchased as cabin sites.

The Mining Claims Occupancy Act passed by Congress in October 1962 enabled people making their principal residence on an improved site on a mining claim to occupy the land which the residence occupied. The law was extended until June 30, 1971.

Buildings necessary for mining facilities are allowed on valid mining claims when discovery is not an issue. It is often necessary to erect buildings on unpatented mining claims to protect equipment, store samples, or house personnel.

In dealing with unauthorized occupancy there is commonly a question of what is authorized use for mining purposes. Even if the claim is valid, the occupancy may exceed that needed for mining purposes. Some habitation of buildings can very well be an authorized use. The administering agency should obtain a technical opinion regarding the claim validity before questioning possible unauthorized occupancy.

Trespass Limitations

The owner of an unpatented mining claim has only limited rights to prevent trespass. He does not necessarily have the right to fence the claim and erect no trespass notices. Under the Multiple Surface Use Act, the surface may be used for nonmining purposes such as hunting and fishing by persons other than the claim holder.

After a valid discovery of valuable mineral has been made, the claimed area is no longer unappropriated public land. The intent of the law is that the same ground cannot be located or possessed by another claimant until such time as the claim is abandoned by the original claimant.

Active mining operations obviously have a right to forbid trespass in and around buildings, mine workings, and mills. For this purpose, fences and no trespassing signs are commonly erected.

Trespass on mining claims may be an accident or innocent mistake, intentional and justifiable, or intentional and not justifiable, and may be committed on the surface or underground. A person entering within the sidelines of another miner's lode claim for the purpose of mining is a trespasser if the vein being mined apexes (see fig. 2) on the miner's claim. The corner monuments of adjacent claims may be placed on the surface of adjacent unpatented or patented mining property for the purposes of squaring the located claim. The consent of the owner is not essential when the encroachment is open and peacefully done. The right of the overlapping locator is limited to the ground outside of the prior located claim or patented ground, except for extralateral rights that might be acquired. Subsequent objection by the prior owner is unavailing.

Prior to the Multiple Surface Use Mining Act of July 23, 1955, claimants commonly took quite literally the statement in the United States Mining Law of 1872 that the locator acquired the exclusive right of possession and enjoyment of all the surface included within the lines of his location. Miners commonly clear timber on a claim for development purposes, used it in surface structures and in underground workings, and sometimes sold the timber outright. Prior to 1955, the miner had no right to sell the timber except for clearance, nor could the Government remove or sell the timber on a claim except in the case of an emergency or insect infestation. In 1955, Congress enacted the Multiple Surface Use Act to curtail nonmining use of the surface of mining claims. While the locator's possession and enjoyment is exclusive for mining purposes, the Government and its licensees may, under proper circumstances, exercise rights of way across the claim so long as in so doing they do not interfere with the mineral development of the claim.

On an inactive mining claim no trespass is committed by people passing through the area hiking, hunting, rock collecting, fishing, or for numerous other reasons. Prospectors and geologists may examine the showing on a claim without prior knowledge of its status as a mining claim or what the ownership is. It is common practice to examine mineral showings and quickly map and sample the surface and underground geology of a prospect without contacting the owner of a claim. If a prospector or geologist spent the time necessary to contact all absentee owners prior to examining all prospects more time would be spent trying to find people than in looking for ore. This type of examination is often to the advantage of the absentee claim owner, for if something of interest is found in the examination the owner will be contacted. If nothing is found he is not bothered unnecessarily.

If the owner of a valid mining claim is working the claim it is the usual custom for the prospector or geologist to stop and talk, and to gain permission to look around.

There is an occasional hermit or recluse who does not want anyone to come near his workings, let alone examine the geology or sample the showings. Unless the showings are of unusual merit the prospect will go undeveloped while such an individual is in possession of the claims.

Federal and State Safety Requirements

The conditions of safety around a developing or operating mine are controlled by both Federal and State laws. The mining States have State mine inspection organizations that inspect and advise on the physical condition of an operation.

On the Federal level, two safety inspection organizations exist. These are Mining Enforcement and Safety Administration (MESA), an agency of the U.S. Department of the Interior, and Occupational Safety and Health Administration (OSHA), an agency of the U.S. Department of Labor. These agencies have prepared pamphlets explaining their functions.

The activities of MESA and some State mine inspection organizations overlap and some coordination exists where the State group has agreed to Federal standards. All three groups keep records and investigate serious accidents and fatalities at mine operations.

The Bureau of Mines has a safety demonstration group, operating out of Boulder City, Nevada, which researches and devises safer methods for performing various tasks.

Most western States have laws requiring that shafts, drill holes, tunnels, and small pits be covered or fenced where they can be a danger to life.

Environmental Regulations

The National Environmental Policy Act of 1969, as interpreted by the courts and implemented in the regulations of the various involved agencies, has added an important dimension to the preparation of plans for exploration and development of resources on the public lands.

An Environmental Impact Statement is not required for every transaction involving resource development. It is possible to prepare a negative declaration when, based on an impact appraisal, no significant impact is anticipated. A nominal impact declaration is also possible. Proper authorities must concur. If National Forest lands are involved, the new regulations apply (Mineral Resources on National Forests Use Under U.S. Mining Laws, Title 36, Code of Federal Regulations, Part 252).

All major mine development programs on public land must comply with appropriate regulations.

At the earliest possible time, the manager of an exploration project with the potential for developing into a producing mine should begin keeping an environmental analysis record of the condition of the air and the water in any stream or lakes on or near the project, the condition of trees and vegetation, and any wildlife disturbance resulting from the project. This environmental baseline data may prove essential in demonstrating what environmental changes occur, if any, as the result of the mining operation.

Environmental analysis and the preparation of the required statements, plans, reports, and following correct, established procedures is a complicated task which usually should be done by experts. In most cases, a mining company bringing a new mine into production employs full-time personal or consultants to do a complete job of environmental analysis. In the case of the small operator, where the project will not financially support expert help, the best plan is to obtain the necessary information from the proper authorities prior to preparing a statement for submittal.

The Mining and Minerals Policy Act of 1970 declares that it is the continuing policy of the Federal Government in the national interest to foster and encourage private enterprise in the development of an economically sound and stable domestic mining industry, the orderly and economic development of domestic resources and reserves, and the reclamation of metals and minerals to help assure the fulfillment of industrial, environmental, and security needs.

Forest Service Regulations

The Forest Service Regulations in Title 36, Code of Federal Regulations, intend to provide for a minimum adverse environmental impact on the National Forest System surface resources from mining operations.

To minimize surface resource impact on mining claims, the regulations require that an operator who is conducting prospecting, exploration, development, mining, or processing of mineral resources in a National Forest file a notice of intent or plan of operations when the proposed work will cause a significant disturbance of the surface resources.

The notice of intent is submitted to the District Ranger for determination of significant disturbance of the surface resources. If significant disturbance will result, in the opinion of the District Ranger, the operator is required to submit a proposed plan of operations.

A notice of intent and a plan of operations need not be submitted for prospecting operations that use existing roads and occasionally remove samples in a manner that will not cause significant surface disturbance. Claim staking subsurface operations, and work that does not disturb vegetation or use mechanical earthmoving equipment are exempt from the notice requirements under the regulations.

The notice of intent to operate must provide enough information to identify the area involved, the nature of the proposed operations, the route of access, and the method of transport. The District Ranger must notify the operator within 15 days if a plan of operations is required.

The notice of intent may be bypassed by filing a plan of operations when the operator is certain that his operations will cause a significant surface disturbance.

The plan of operations must include:

1. The name and legal mailing address of the operator (and claimants if they are not the operators) and their lessees, assigns, or designees.

2. A map or sketch showing information sufficient to locate the proposed area of operations on the ground, existing and proposed roads or access routes to be used in connection with the operations as set forth in the regulations, and the approximate location and size of areas where surface resources will be disturbed.

3. Information sufficient to describe or identify the type of operations proposed and how they would be conducted, the type and standard of existing and proposed roads or access routes, the means of transportation used or to be used, the period during which the proposed activity will take place, and measures to be taken to meet the requirements for environmental protection.

The plan of operations must cover the requirements reasonably foreseen for the operation for the full estimated period of activity. Whenever the operator proposes operations not foreseen in the initial plan, he must file a supplemental plan or plans.

Approval must be obtained of a proposal to build an access road to the project area to begin any planned operations. Without reasonable access, many exploration projects are not viable. Exploration activity in the National Forests can be delayed by requirements imposed under the National Environmental Policy Act.

After the Forest Service completes an environmental analysis in connection with each proposed operating plan, the Forest Service officer will determine whether an environmental statement is required. Not every plan of operations, supplemental plan, or modification will involve the preparation of an environmental statement. Environmental impacts will vary substantially depending on whether the nature of operations is prospecting, exploration, development, or processing, and on the scope of operations (such as size of operations, construction required, length of operations, and equipment required) resulting in varying degrees of disturbance to vegetative resources, soil, water, air, or wildlife. The Forest Service will prepare any environmental statements that may be required.

When the District Ranger receives the proposed plan of operations he must promptly acknowledge its receipt.

The authorized officer must make an environmental analysis within 30 days and:

1. Notify the operator that he has approved the plan of operations, or

2. Notify the operator that the proposed operations are such as not to require an operating plan; or

3. Notify the operator of any changes in, or additions to, the plan of operations deemed necessary to meet the purpose of the regulations; or

4. Notify the operator that the plan is being reviewed, but that more time, not to exceed an additional 60 days, is necessary to complete

the review, setting forth the reasons why additional time is needed. Provided, however, that days during which the area of operations is inaccessible for inspection shall not be included when computing the 60-day period; or

5. Notify the operator that the plan cannot be approved until a final environmental statement has been prepared and filed with the Council on Environmental Quality.

After an operation begins, the Forest Service has the right to inspect the operation and issue notices of noncompliance with the plan. Noncompliance notices must indicate what is needed to correct the problems identified.

Some considerations in environmental protection are: air, water, solid wastes, scenic values, fish and wildlife habitat, roads, reclamation, erosion, landslides, water runoff, control of toxic materials, reshaping and revegetation of disturbed areas, and rehabilitation of fish and wildlife habitat when the operation is completed.

After the operation ceases permanently, the site must be cleaned up within a reasonable time. This may include removing equipment and structures or other facilities.

When a plan of operations is filed, a bond may be required assuring that reclamation is completed in accordance with the plan of operations.

While awaiting approval of the plan of operations the authorized officer will approve the work needed to perform assessment requirements.

During operations under an approved plan, the authorized officer may request a modification to minimize unforeseen significant disturbances. The Forest Service may be required to suggest reasonable means of correcting the problem. The Forest Service may attempt to close down an operation that is causing irreparable and unnecessary injury to the surface resources.

The Forest Service will arrange for consultation with the Geological Survey and the Bureau of Mines or other appropriate U.S. Department of Interior agencies on significant technical questions of geology, development systems, techniques, and equipment. The operator may request this type of consultation.

All of the information will be available for examination by the public, except for information and data designated as confidential by the operator. Confidential information might include trade secrets, privileged financial and commericial information such as the known or estimated outline of a mineral deposit and its exact location, the details of an exploration project, and other competitive commercial information.

An operator aggrieved by a decision of an authorized officer may file an administrative appeal through the Forest Service appeal system set out in the regulations. Appeals beyond the prescribed system should go through the appropriate courts.

The regulations are applicable in Wilderness and Primitive Areas as long as the mining laws apply in these areas.

These regulations are a part of a vigorous program to minimize surface damage from mining in the National Forests. Care will be taken that the regulations are not unreasonably used to restrict the statutory right that the miner has to prospect for, and develop, minerals in public lands open to entry.

The regulations are in Title 36, Code of Federal Regulations. A question and answer pamphlet on this subject has been prepared by the Forest Service.

PROSPECTING

The role of the small prospector-miner has been somewhat distorted by romanticists, who gloss over the complex series of steps necessary to take a prospect into production. Perhaps only in the early gold placers of California, Idaho, and Montana were conditions favorable for the individual miner of early years to develop a small profitmaking operation while keeping himself fed and clothed, using no resources other than his own sound health and optimism. From time to time, other commodities are mentioned as the hope or refuge of the small miner, such as tungsten, uranium, and quicksilver, but over the long run, most metal production comes from large efficient operations requiring huge capital investment.

In the rare instance where a prospector is successful in finding a promising mineral showing, his first thought is almost always to sell out to someone more interested than he in developing a mine. Much of his off-season activity is in the submittal of his prospects to established companies. The prospector does not consider himself to be a miner, although he often seeks temporary employment at an operating mine in order to replenish supplies, pay bills, or to wait out the winter season.

There is obvious romantic appeal and adventure in prospecting, and the possible financial reward would seemingly be an irresistible incentive. Great personal satisfaction can be derived from watching one's preliminary idea of a prospect develop into an important resource. However, few people seem able to become proficient at prospecting or to stay at it long enough to be reasonably confident of success.

Considering the nature of ore deposits, minerals, and the enclosing wall rocks, it is obvious that the fundamental basis for all prospecting is the science of geology. To be effective, the prospector must possess considerable geologic knowledge and insight. It does not follow, however, that the prospector must be a geologist. Many geologists are poor prospectors. They are trained to move relatively rapidly across the ground, recording and interpreting a variety of information, often of little direct significance to ore potential but necessary for complete reports and maps.

Most professional geologists are salaried employees or contractors and are reimbursed for field expenses. Few prospectors are supported, if at all, beyond a minimum subsistence level. The typical prospector depends largely or entirely upon the development of his mineral discovery for financial reward, recognition, and his own personal sense of achievement. A small number of professional geologists work independently in mineral exploration, obtaining financial support from small companies or investors' syndicates.

Corporate geologists involved in the search for minerals most often work as a part of a team of professional specialists, technicians, contractors, and consultants. The exact makeup of this group varies from one area to another, and depends to a great extent upon the particular concepts and techniques employed.

Typically, in addition to the geologist,such diverse talents are represented as those of the geochemist, geophysicist, mining engineer, metallurgist, attorney, mineral economist, photointerpreter, computer expert, laboratory scientist (such as a mineralogist), and field technician. Any of these company personnel might refer to himself or be called an explorationist. Although the exploration work that he performs might sometimes be described as prospecting, he does not think of himself as a prospector, nor is it likely that anyone else would refer to him in this manner.

Usually the corporate explorationist's activities are called mineral exploration, or regional mineral exploration where there might be risk of confusion with physical exploration--the systematic probing of a specific prospect by trenching, drilling, or underground work.

Prospecting is therefore usually the work of the prospector or the independent geologist, and includes ground reconnaissance and preliminary aerial observations. Only in special situations is systematic physical work such as sampling and drilling done at this stage. A corporate group usually refers to their preliminary mineral reconnaissance as mineral exploration. Exploration at the project level, such as drilling, trenching, and digging underground openings, is called simply exploration, and considerable confusion can result when someone unfamiliar with the specific definitions used by an exploration group first comes in contact with them.

Prospectors can rarely afford to explore their own prospects to any extent, and must interest a well financed, established mining organization. In general, most prospecting or regional mineral exploration is done before property acquisition is undertaken. Exploration is almost never started until property acquisition is complete.

The Conventional Prospector

There are few people actively interested in prospecting today who do not have some basic training in science or engineering, if nothing more than the typical requirements for graduation from high school or an infantryman's map reading course. Each year the opportunities expand for the average interested person to study subjects such as basic geology and mineralogy. Short courses in prospecting or in specialized aspects of mineral exploration can be attended by the private individual, although the location and timing of such offerings are not always convenient.

Rather than describe today's conventional prospector as lacking in formal training, it would be more accurate to refer to him as a person who has not been completely trained as a professional geologist and does not undertake geologic work for others on a professional basis. A proficient prospector will have trained himself well enough to be able to conduct independent investigations into geological relationships he knows to be, or has been told are, important in ore localization.

The greatest opportunity for the modern prospector is in following the development of new concepts of ore localization and new techniques and instrumentation, which will allow him to confidently go back into areas intensively prospected before by oldtimers. If the prospector cannot find a new ore target or a new approach, he depends far more upon a stroke of luck than prudence would justify.

An easily read and comprehensive book on prospecting has been published by the Canadian Department of Mines and Technical Surveys ("Prospecting in Canada," by A. H. Lang, Third edition, 1970). This serious treatment of the subject emphasizes Canadian conditions, but most of it applies to prospecting anywhere. It is an excellent source of information for both novice and professional.

The modern prospector has advantages over the oldtimer in the form of better equipment, 4-wheel drive surface vehicles, and aircraft. Access into areas of interest is far better, and water, diet, and health conditions are not the serious problems they were under more primitive circumstances. Some mining experts would counter with the observation that the early prospector had to go in and stay in, making him much more effective than some of the modern dilettantes.

To become truly competent as a prospector, a person should be prepared to devote at least as much time as he might to become skilled at some other occupation such as automobile mechanic or carpenter. He should read trade journals such as the "Engineering and Mining Journal," newspapers such as the "Northern Miner," and Government publications such as "Mineral Facts and Problems" by the Bureau of Mines and "United States Mineral Resources" by the Geological Survey. The latter volume furnishes many important facts concerning most mineral resources of interest, and contains many specific suggestions on prospecting for various ore types.

To a lesser extent than in other vocations, it is possible for the beginner to seek out a seasoned professional prospector and to learn from him directly. Such an apprenticeship would obviously be of great value to the novice, but there is rarely an incentive for the experienced hand to share his knowledge and experience.

An experienced prospector who can effectively communicate with people has little difficulty today in obtaining company support or the backing of a small investment syndicate composed of local professional or business people. The United States tax laws encourage such individual investments, inasmuch as some exploration expenses can be written off against other income. Long-term capital gain schedules can be applied to some profits, and depletion allowances are an additional incentive to the investor.

For a variety of reasons, the number of full-time professional prospectors in western North America has steadily dwindled, and most of the important discoveries of recent years, particularly in the United States, are the direct result of mineral exploration done by corporations or by independent geologists.

Amateur Prospectors

In recent years, as full-time professional prospectors have almost disappeared from the scene, amateur prospectors have become far more numerous. To many outside of the mining business it is difficult to distinguish between the two.

The publicity, somtimes highly distorted, given to rushes such as the uranium boom of the 1950's, the convenience of modern off-road vehicles,and the increasing amount of leisure time available to so many, have combined to produce tens of thousands of amateur prospectors. Some of these individuals make great efforts to equip and train themselves, and they are capable of finding prospects worthy of exploration and development. However, the majority of the amateurs are poorly motivated and so lacking in the most rudimentary knowledge that they create difficulties for those seriously engaged in prospecting and exploration.

The amateur's common lack of consideration for the rights of land owners, his abuse of laws and regulations, and his ill-conceived bulldozing of the surface have become so offensive that there is mounting pressure for drastic restrictions on all prospecting and exploration activities. A great deal of wisdom and fine judgment will be required in finding ways to regulate the recreationist-prospector while not unduly restricing serious prospectors and geologists upon whom the Nation depends for future mineral discoveries.

Regional Mineral Exploration

When an established mineral organization undertakes the exploration of a large new area, some considerations are simple and straightforward. Aside from the obvious desire to continue in the business of producing minerals, the organization may consider:

1. Need to diversify.
2. Need to satisfy customer demand for a metal. Some manufacturers, after years of dependence upon outside suppliers, may decide to enter the mining field themselves.
3. State laws, local regulations, and attitudes may encourage exploration in a given region.
4. The company may be well established in some other profitable resource industry such as petroleum, and be prohibited by antitrust laws from purchasing ongoing mineral-producing companies. In such cases,entry into the mining business is said to be "via the exploration route."
5. The desire to achieve or maintain a reputation as the major supplier of a certain commodity, so that exploration leads of all kinds are investigated for this commodity, wherever they may be found.

As preliminary planning continues, a combination of such considerations as these, guided to a large degree by the personal judgment of a few individual decision makers, will quickly focus attention upon certain areas, often principally by a process of elimination. The resulting area of interest might be roughly 100,000 square miles in extent, something less than the area of one of the western States. It may not be possible to further narrow down the area of interest without at least a small amount of preliminary field reconnaissance.

In preliminary planning, a certain amount of "elephant country" philosophy is involved in selecting regions in which to hunt. That is, one goes to Africa to hunt elephants. For example, in planning the exploration for large low-grade copper deposits, the obvious potential of the Arizona-New Mexico-Sonora region cannot be matched elsewhere. Here,many great porphyry copper deposits are developed literally within sight of each other, and large new deposits continue to be discovered in the region. There is probably no other area on earth so intensively explored during the past decade.

Wyoming and northwestern New Mexico have an impressive number of large, bedded uranium deposits that can be mined by open pit methods, and general geologic conditions are permissive of many more such occurrences. In north-central Nevada, a zone consisting of a dozen or so low-grade "invisible" gold deposits has recently been identified in which the important new Carlin deposit (the first major open pit gold mine in North America) was recently discovered and is now being mined. Geologic conditions in the surrounding region suggest that similar additional deposits remain undiscovered and, in terms of hunting for gold deposits of the Carlin type, this area is spoken of as "elephant country."

Exploration Concepts

Once an area of manageable size has been selected for regional mineral exploration, the first step is to assemble all pertinent information such as published geologic maps and reports, private company data, commodity maps, topographic map coverage, and aerial photography. Some or all of these basic data are usually compiled on some suitable small-scale map, such as the 1:250,000 U.S. Army Map Service sheets published by the Geological Survey. If the quality of published geologic mapping permits, the basic geology, or skeletonized versions of it, is compiled. The objective of this work is to define those areas which contain the right combination of geological conditions to localize an ore deposit of the kind sought.

To illustrate the procedure, one of the ore types of interest in western North America today is tungsten (scheelite, $CaWO_4$) mineralization found in distinctive skarn zones (fig. 3), where lime-silicate alteration formed around certain igneous intrusions in calcium-rich rocks such as limestone. The compilation for exploration of this ore type would emphasize the following geologic characteristics of the ore type; and the information would be gathered from literally thousands of different published sources:

1. The location and character of igneous intrusives.
2. The distribution of calcium-rich formations.
3. Previously discovered scheelite mineralization.
4. Showings of skarn.
5. Prospecting activity, particularly near known or suspected igneous intrusions.
6. Areas overlain by younger sedimentary and volcanic formations should be delineated carefully, for these rocks cover the tungsten deposits.

Although this is a simplified description of the steps taken to evaluate a region for a simple ore type, it illustrates the approach often used for whatever kind of ore sought. The emphasis on different kinds of geologic evidence varies from one ore type to another. The characteristic that may be important in searching for one kind of ore may have little or no significance in hunting for another. A more detailed discussion of the criteria for the recognition of various ore types is given in the chapter titled "Exploration."

A number of features of interest in regional mineral exploration can be interpreted directly on vertical aerial photographs, available from the various Government mapping agencies or taken especially for the purpose.

Most regional exploration leaves few marks upon the ground, and the work of the prospector or geologist cannot be detected after several storms wash away the imprint of his boot. For every pit or other obvious sign of fomer prospectors' interest, there are thousands of acres where the signs of mineralization were too feeble to have attracted his attention. Much exploration today is done from aircraft or surface vehicles identical in every respect to other surface users, and only the most experienced observer is able to distinguish the explorationist's

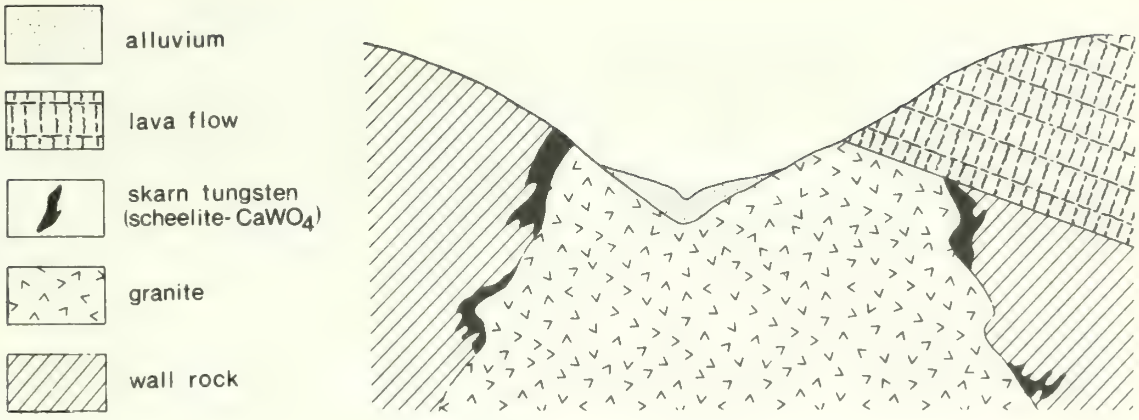


Figure 3.--Skarn tungsten mineralization.

activity from the comings and goings of other scientists, resource managers, and outdoor enthusiasts.

The corporate exploration geologist will usually have received extensive indoctrination from his superiors concerning the various rules to be observed on public land and the need for cooperation with agency representatives. He will be correspondingly receptive to reasonable suggestions or instructions, particularly where the law or regulation clearly covers the situation in question.

Preliminary Evaluation of Exploration Results

Once specific areas of mineral potential have been defined, the results of prospecting or reconnaissance work are submitted to management before proceeding with property acquisition and physical exploration. Every mineral exploration project requires preliminary estimation of the merit of starting the work required to explore and develop the prospect.

The prospector or geologist makes an initial rough estimate of the general form and character of the expected ore body. The prospector uses this original concept of ore in attempting to interest people in taking over or financing his prospect. The geologist uses his concept in presenting the project to management.

Often the preliminary report contains carefully prepared maps, quantitative data, photographs, and geologic cross sections. In larger companies, where many different exploration proposals may be considered simultaneously at regularly scheduled meetings, simplified diagrams are prepared to convey complex relationships and to serve as a focal point for discussion and decisionmaking.

Each mining group or company has a different objective in terms of size and type of operation desired. The small mine that might be financially successful for a small group or individual is normally of no interest to a major corporation. Mining ventures must be capable of producing earnings of at least 5 to 10 cents per share if they are to be of interest to the typical mining company.

Up to this point, the area being explored may have gone through a continuing process of evaluation, however unsophisticated and incomplete. Analysis of cash flow is almost always done before the decision is made to proceed. These preliminary evaluations are usually not identified as "feasibility studies," although some of the same methods may be used in deciding whether or not to continue. A major feasibility study and thorough evaluation is required to justify the multimillion dollar capital investment typical of a major mining operation.

EXPLORATION

The selection of a small area for detailed exploration may be the result of regional reconnaissance, a spot check of promising geologic situations described in published literature, submittal of a proposal by a prospector or independent geologist, or the decision to restudy an old mine or mining district.

The area selected for detailed work usually embraces additional ground outside the area of actual interest. This surrounding ground may not be concentric to the prime target area. A total of less than a square mile to as much as 10 square miles of land may be involved, depending upon the type of mineralization being explored. For example, the area required for a small high-grade mercury or gold prospect may consist of 10 to 100 acres, a massive sulphide base metal prospect a square mile or more, and major potash or phosphate potential might require acquisition of several square miles of property.

Mineral rights are secured as soon as possible after the area has been determined to have exploration potential, although details of property acquisition sometimes go on during the planning and initiation of physical exploration work. It is considered good practice to locate open ground before making initial contact with the land owners and prior claimants in the area. This sometimes leads to misunderstandings, because ranchers often do not remember the relationship between their private land holdings and various surface leases and informal agreements. They may become upset over activity on what they have come to consider their private property.

When undertaking property acquisition, it is necessary to move quickly, stake all open ground, and undertake negotiations with private land owners and prior claimants afterward, while completing the location requirements on the staked ground. A period of relative quiet usually follows this initial burst of activity. Local residents may become somewhat frustrated at the apparent lack of followup just when they have begun to be interested in developments. After sufficient ground has been acquired, detailed plans for exploration are made, usually at a regional office some distance removed from the exploration project site.

The individual States specify the claim location requirements, and no two laws are exactly alike. Most States, for example, Colorado and Nevada, have changed their laws to provide for staking claims without performing the physical "location work" which became so damaging to the surface environment after the advent of the bulldozer. Some States require a map showing the location of the claim. This is done so that other interested parties can find the claim on the ground, and to eliminate the fraudulent practice of moving claims over discoveries made by others--the major abuse of the mining laws from the miner's point of view.

These new State laws eliminate poorly planned trenching and bulldozing at the time of claim location, but of course do not restrict or limit the carefully planned exploration work the claimant may later do, nor minimize assessment work requirements.

In many regions, indiscriminate bulldozer work in performance of claim-staking requirements is a far more widespread and serious disturbance of the surface than actual mining. Such senseless scraping of the surface should be discouraged in those States where the locator has the option of not doing physical location work upon the ground.

Planning

After mineral rights have been acquired and preliminary estimates of profitability made, attention turns to the choice of exploration methods to be used and the sequence in which they are to be employed. Personnel assignments are made, outside services contracted, and necessary equipment obtained and allocated.

Personnel

A project manager is appointed, his title and professional specialty depending upon the kind of exploration work to be done. Most often he will be a geologist, and he will usually remain solely occupied with this project through to completion.

All important contact should be with the project manager, for often he alone has the knowedge and authority to make decisions and to commit the company to a particular course of action. Contractors' employees are particularly to be avoided, for they may have an erroneous conception of the objectives of the work, and are rarely authorized to talk with outsiders.

Exploration projects such as drilling programs are commonly company training grounds for recent graduates and college students on summer vacation. Such junior personnel usually have an imperfect understanding of the overall objectives of the program. Unless it is made very clear that such employees can be contacted, unauthorized attempts to obtain detailed information directly from them are almost certain to jeopardize relationships with the project manager.

Access

Provision must be made for acess to the drill sites, movement of staff and contractor personnel, water for drilling supplies, and removal of samples. In the dry season, in highly fractured ground, exploration drilling may require thousands of gallons of water per day, and a major aspect of the work becomes the constant movement of large water trucks. Where water is scarce, the drill contractor may purchase it on some such basis as a flat fee per load paid to the owner of a nearby well or pond. The drills, tank trucks, and smaller vehicles used in transporting men and equipment are heavy duty, usually with 4-wheel drive, capable of negotiating steep terrain over very poor trails and roads.

When larger drills are employed, flat pads as much as half an acre in size are leveled to site the equipment, install mud tanks, and provide for sample collection and parking for personnel. The smaller, skid-mounted drill rigs can be moved under their own power by utilizing the cable and draw works in a winching arrangement, to move them over bare ground and up steep slopes to unprepared sites. Auxiliary equipment such as pumps and tanks can be pulled into position by the drill.

Exploration drills and related machines are powered by gasoline or diesel engines, and require a modest amount of fuel storage at the drill site. Electricity requirements are small, and supplied by generators integral within the equipment, or by small portable power plants of 1/2- to 5-kilowatt capacity.

Trailer-mounted air compressors are used in some kinds of exploration drilling. Small track-mounted, air-operated drills are available. These are maneuverable enough to work in rough country without preparing elaborate drill roads or constructing drill sites.

If terrain conditions are unusually severe or if road construction is impossible, helicopters can be used to mobilize and service the drills, although at much higher cost. When not carefully planned and efficiently utilized, helicopter servicing of exploration drills becomes prohibitively expensive.

Because of the large size of the drilling machinery required on most modern exploration projects, it is rarely feasible to use horses to mobilize and service the work. The small portable drills advertised in rockhound newspapers are not adequate for most exploration work, and find application only in very special situations.

Occupancy

Where feasible, exploration work is based from established motels, hunting and fishing camps, or ranches or farms. Families are usually housed in mobile homes located in the nearest population center where utility hookups are available. In more remote situations, semipermanent or permanent buildings may be necessary, particularly after encouraging results are obtained from preliminary drilling. The first requirement is usually for sample handling in a geologic warehouse that can be locked.

Communications

Elaborate communications are usually not required on exploration projects except in the most remote situations. On large projects, or when work extends into the severe weather season, company or contractor may operate radios to facilitate movement of men, equipment, and supplies, and to provide a measure of security in the event of sudden illness or accidental injury.

Property Adjustments

As attention focuses upon the specific target area, it is sometimes necessary to make adjustments in property or in the conditions of mineral ownership. For example, it may become obvious that a certain area may be the only suitable site for disposal of mill tailings, and planning should begin to consider this as a relatively inflexible fact.

Before actual discovery of ore is made, a minor overlapping of prior claimants' locations might easily be resolved by a simple agreement to share royalty on production that might come from the disputed area. It may be possible to secure agreement from all mineral claimants that vertical sidelines will determine mineral ownership rather than leave open the complexities of extralateral rights. Careful surveys of particularly troublesome claim boundaries may be contracted to a U.S. Mineral Surveyor with everyone's agreement to abide by his survey. Reasonable discussion is usually possible before ore is found. After ore is found, the same suggestion might result in an immediate lawsuit or the threat of lease cancellation.

Contact With Federal Agencies

In the earliest stages of planning physical exploration work, consideration must be given to the operating plan to be submitted to the Forest Service if the claims are on National Forest land. Up to this point, particularly if it was possible to locate the claims without doing bulldozer work or constructing roads, the surface disturbance being minimal, the job may have been done without an operating plan.

Construction or improvement of access roads, drill sites, trenches, pits, or landing areas for aircraft make it necessary to secure an approved operating plan. The location and nature of the work must be specified, and the work done in such a manner as to minimize surface damage and coordinate with other surface uses.

The intent is not to regulate the mining industry or to manage mineral resources, but to minimize damage to the surface environment. In some cases it will be necessary for the operator to submit information normally regarded as secret or competitive within the mining industry. In such cases, information necessary for approval of the operating plan will be furnished on a confidential, need-to-know basis, preferably to a Forest Service mining engineer or geologist.

Geological Exploration Methods

Understanding of the geology of the ore deposit and its general geologic setting is absolutely necessary at every step in prospecting exploration, and development. The principal method of portrayal of this information is through the use of geologic maps and cross sections, which are constantly reworked and updated as work progresses and new information becomes available. Geologic maps and sections are fundamental in exploration planning, correlation and evaluation of preliminary results, and in reporting to management.

The geologic field methods most commonly used are:

1. Geological detail is plotted directly on field sheets made from maps published by the U.S. Government, or made by Kelsh plotter using large-scale aerial photographs taken especially for the purpose. Geology may be mapped directly on the aerial photographs from which the Kelsh map was made, or on enlargements of them, and transferred to the topographic base afterward.

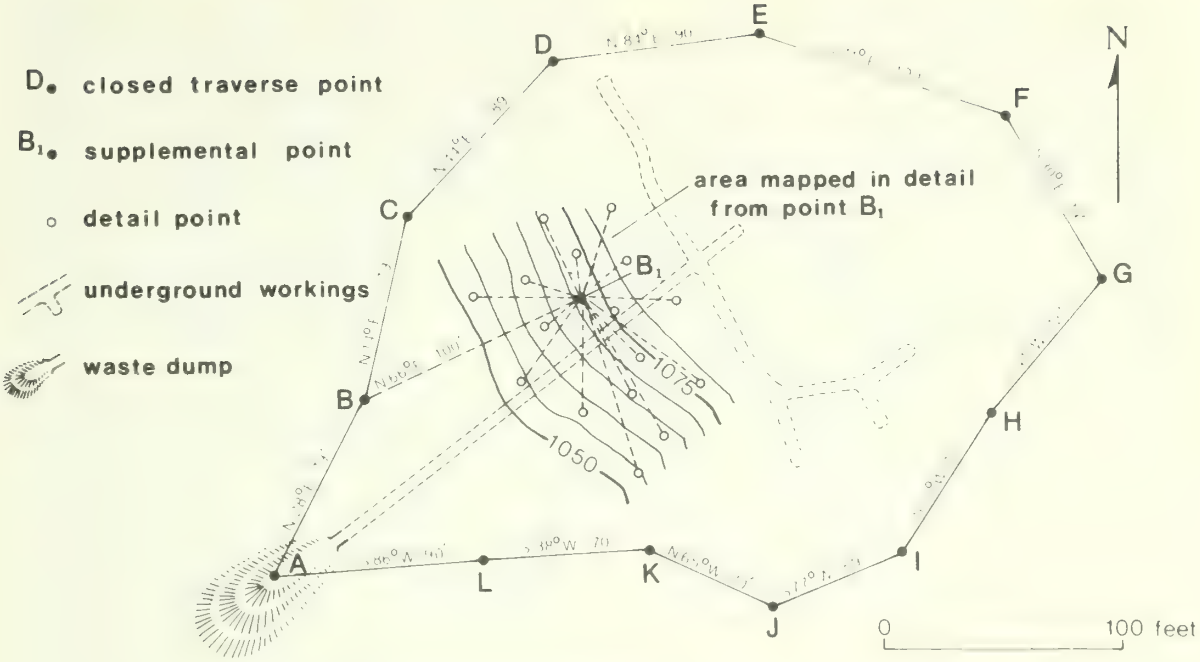


Figure 4.--Compass and tape method of mapping small prospects.

2. Transit and stadia are used to prepare large-scale topographic maps and to record geologic detail simultaneously. The plane table and alidade method, popular with Geological Survey and petroleum company geologists, is little used in mineral exploration.

3. Brunton compass and simple optical rangefinders are sometimes used in detailed mapping where extreme accuracy is not required. This method is popular with many geologists because it is possible to work alone.

4. Brunton compass and tape (fig. 4) sometimes used to provide base control, make the topographic map, and to record geologic detail where a large-scale map is required of a small area. A closed Brunton compass and tape traverse is usually surveyed as the base control.

5. Some geologists do preliminary geologic mapping of prospects on enlargements of vertical aerial photographs or small-scale topographic maps available from various Government agencies. The initial saving in time and cost is more than offset by the frustration and slow pace of mapping this way. Serious errors of distortion result from enlargement to a scale suitable for exploration work.

The geologic details shown on maps and sections are observed in outcrops, excavations, underground openings, and samples taken from drill holes. The data obtained between surface bedrock observations are plotted by careful projection and matching of known data. Inspection of float (fragments of rock lying in the soil that are large enough to be visually studied) is a method much used in projecting geology.

Criteria for Ore Recognition

The geologic features of importance in mineral exploration vary considerably from one ore type to another, and what might be of importance in one ore type may be of minor significance in another. However, there are a few criteria for the recognition of ore that are almost always considered, regardless of ore type, and a brief listing and discussion will serve to illustrate the methods of the geologist in exploration work. Some criteria for ore recognition are:

1. Igneous rock affiliation.
2. Host rock association.
3. Wall rock alteration.

4. Age of mineralization.
5. Gangue mineral association.
6. Trace metal association.
7. Structural controls.
8. Physiographic expression.
9. Weathering effects.
10. Ore mineralogy.

Igneous rock affiliation--Many ore deposits are associated with or contained within certain kinds of igneous rocks. For example, chromite ores are always found in a special kind of iron-rich rock. Some types of tungsten mineralization are always found associated with certain granitic rocks.

Host rock association--Certain kinds of wall rock act as host to specific ore types. For example, ancient reef deposits, similar to the modern coral reefs of the South Pacific, are interlayered within marine formations such as limestone. Fossil reefs are an important locus for a variety of important precious and base metal deposits.

Wall rock alteration--The mineralizing fluids that deposit ores sometimes permeate outward into the enclosing host rock, causing subtle changes in a ring-shaped contact zone (aureole) around the ore body (fig. 5). For example, limestone surrounding certain silver-lead ores is recrystallized to dolomite, coarsening the texture of the rock slightly, and making it visibly lighter in color. The aureole of wall rock alteration is quite useful in mineral exploration, for it is much larger than the ore deposit itself, and usually is subtle enough to have escaped notice of the early prospectors and miners.

Age of mineralization--Some ore deposits occur only in rocks of a definite age. For example, much of the world's potash is Permian in age (280 to 225 million years), and the bedded barite deposits of the West are largely restricted to formations of Silurian and Devonian age (430 to 345 millions years). Many such simple age relationships are only now becoming generally recognized, and the concept will be helpful in the mineral evaluation of many regions.

Gangue mineral association--Many ore types have distinctive gangue mineral associations (undesired minerals associated with the ore) that can be of use in mineral exploration. For example, two major regional ore belts, the Mother Lode gold and the Foothills base metal zones of California come together and mingle northwest of Yosemite National Park. Prospectors quickly learned that the appearance of barite in float or in the prospect pan was good evidence that the mineralization was of the base metal type, not gold.

Trace metal associations--Many kinds of ore deposits have distinct combinations of minute amounts of metal found in association with the principal ore metal, helping to distinguish one ore type from another. For example, the copper deposit containing nickel and cobalt is of entirely different character than a copper-molybdenum association.

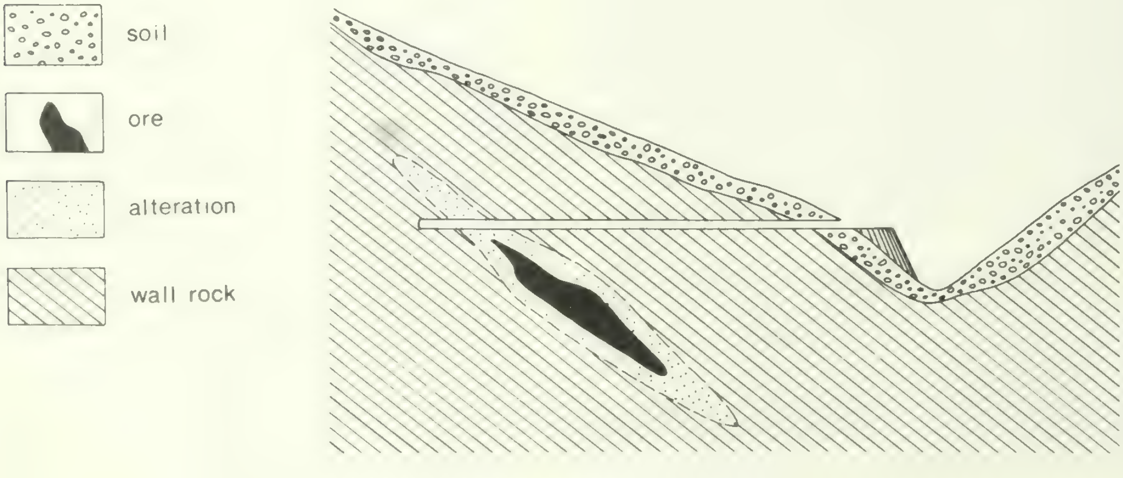


Figure 5.--Wall rock alteration as a guide to ore.

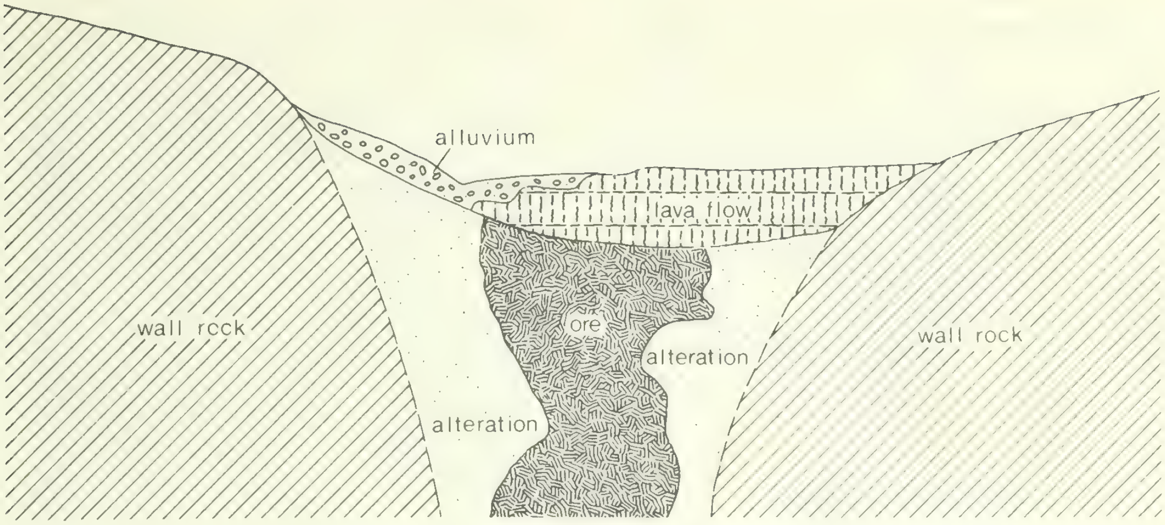


Figure 6.--Physiographic expression of ore.

Structural controls--The analysis of structural control of ore is usually of prime importance in planning exploration, development, and production. On a regional scale, ore deposits may be found in elongated rows of individual ore occurrences or clusters of occurrences which are referred to as mineral belts or mineral lineaments. Along these trends, above-average potential for ore exists. On a more restricted scale, the ore types of a given district may occur along a single fault or beneath a thrust plane, focusing attention upon an unexplored block of ground. Such relationships may become apparent only after the most painstaking detailed geologic mapping.

Physiographic expression--Individual ore deposits, and sometimes entire mining districts, are commonly altered, mineralized, and weathered so that the rock matrix consists essentially of chemically unstable or soft, easily weathered minerals and rocks (fig. 6). Erosion cuts into such zones, and the resulting depressions are often filled with gravel and lava flows and are usually densely overgrown with vegetation, all but concealing evidence of mineralization. The recognition of mineralization fringe effects, and the lateral projection of such indications beneath cover, is an approach used by many explorationists.

Weathering effects--Many of the mineral deposits currently of interest consist of relatively small specks of valuable mineral scattered through a worthless rock matrix. The ore minerals themselves are often chemically unstable under the weathering conditions at and near the surface. The ore minerals of copper, silver, and uranium, for example, rarely survive intense weathering and are decomposed so that some or all of the metal is flushed from the outcrop in aqueous solution (ground water). This near-surface zone of leaching and flushing is called the leached capping, and it may contain none of the ore minerals characteristic of the unweathered ore deposit below. The recognition of leached cap rock has been a very successful tool of the modern exploration geologist, because the various stable oxides, sulphates, and carbonates of metals most often remaining in outcrop are extremely difficult to recognize and were easily missed by earlier explorers.

Ore mineralogy--In some instances the mineralogy of the ore itself may be important. For example, aluminum is one of the most abundant elements in the earth's crust, yet only bauxite (a relatively rare mixture of aluminum hydroxides) has been mined as an ore of aluminum.

Most geologists have a checklist of ore criteria they think important for each ore type of interest. They might refer to the total picture of all criteria considered together, as a "conceptual model" of that type of ore occurrence. They may also have definite ideas about the size, shape, and grade to be expected of this hypothetical ore deposit. Obviously, a conceptual model can be of great help in planning exploration, during mapping and drilling, and in all phases of the evaluation of results, if the risks inherent in any generalization are kept in mind. The use of a formal conceptual model is often found to improve communications with management and to facilitate discussions between explorationists, such as those between geologist and geophysicist.

Geochemical Exploration Methods

The recent great progress made in rapid, inexpensive methods of trace metal analysis has resulted in a variety of applications in geology. These are referred to as geochemistry. In mineral exploration, geochemistry is broadly applied in two different situations. Numerous samples are often collected incidental to other exploration work, such as geological mapping of underground workings. These samples are submitted for trace metal analysis and the results incorporated into the overall geologic interpretation. No confusion seems to result in calling this work geochemistry, even though the same term is used to describe trace metal analysis of air, water, soil, and rock materials as an exploration method in its own right.

Reconnaissance Geochemistry

In applying geochemistry in regional mineral exploration, the basic requirement is for a rapid, relatively inexpensive technique that will efficiently narrow interest to areas small enough to explore by more detailed methods. Simple observations can be made from the air, either visually, by the person in charge of the work, or by interpretation of aerial photography. Black and white and color photographs are used, and false color effects are obtained by using special films and filters to emphasize unusual rock, soil, and vegetative effects.

Geobotanical methods of prospecting involve the visual observation of changes in the normal appearance or distribution of certain vegetation. The plant may show visible toxic effects such as deformed or discolored leaves, or unusual size. In some cases the very presence or absence of a given kind of vegetation may betray unusual nutritive or toxic conditions. In one region, the discoloration of the leaves of a common tree, observed from fixed-wing aircraft, led to the discovery of a major new copper district. In another area, the wide spacing of a shrub common to the region, with intervening ground bare of grass, is a good indication of the host rock of nickel silicate mineralization.

Various air "sniffing" devices are coming into use in regional mineral exploration. Airborne, vehicle-mounted, and sample station detectors have been designed to measure such indicators as mercury vapor, sulfur dioxide, and radon gas in atmospheric and soil air, which may betray a weathering ore deposit below the surface, perhaps even beneath a considerable thickness of soil.

The geochemistry of surface and underground water is a reconnaissance exploration tool. Samples from springs, wells, and streams may contain trace amounts of metal in solution, indicating that the water has come in contact with a concentration of the metal, perhaps an ore deposit. Where surface water is insufficient for adequate sample coverage, a popular method is to analyze small samples of silt from the streambed itself. This method enjoys great popularity in more arid regions because it is straightforward and can be done by technicians. However, results have proved very difficult to interpret and follow up, and much less stream sediment sampling is being done today than 10 years ago.

Rocks

Perhaps the most favored detailed geochemical exploration method at present is the collection of rock chip samples, analyzed to determine if significant patterns may guide exploration. Many of the elements contained in ore deposits, and the surrounding envelope of altered rock, are not chemically stable in outcrop and may be leached from the surface zone. For example, a relatively high grade vein of copper

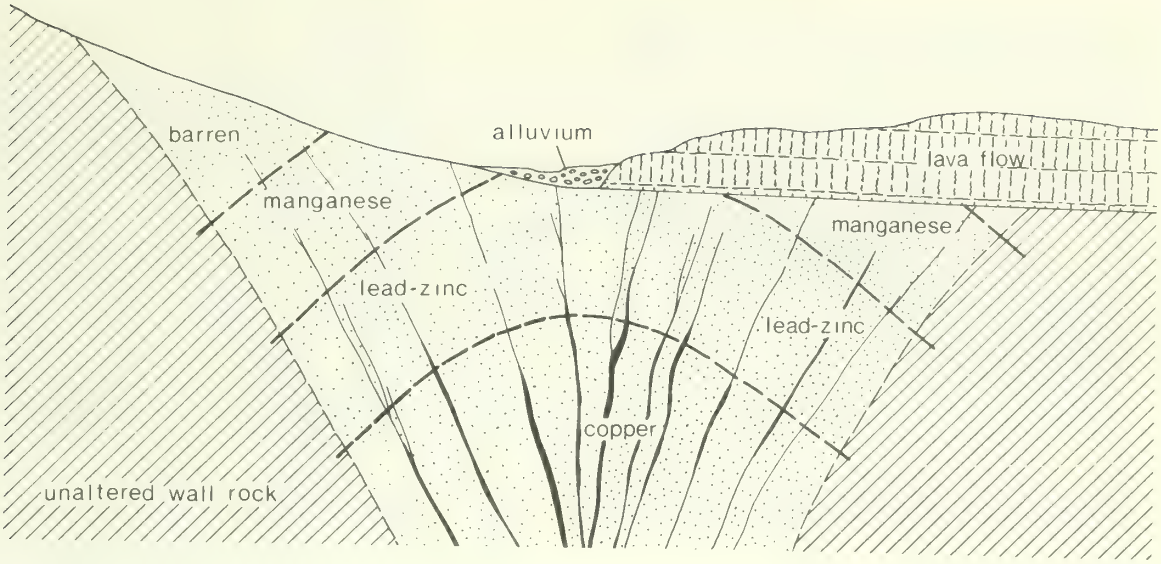


Figure 7.--Metal zoning in a vein system.

may be so thoroughly weathered and flushed from the surface that no obvious copper minerals can be visually identified, and geochemical values may be far below the metal content of minable ore, although still high enough to be indicative of commercial possibilities.

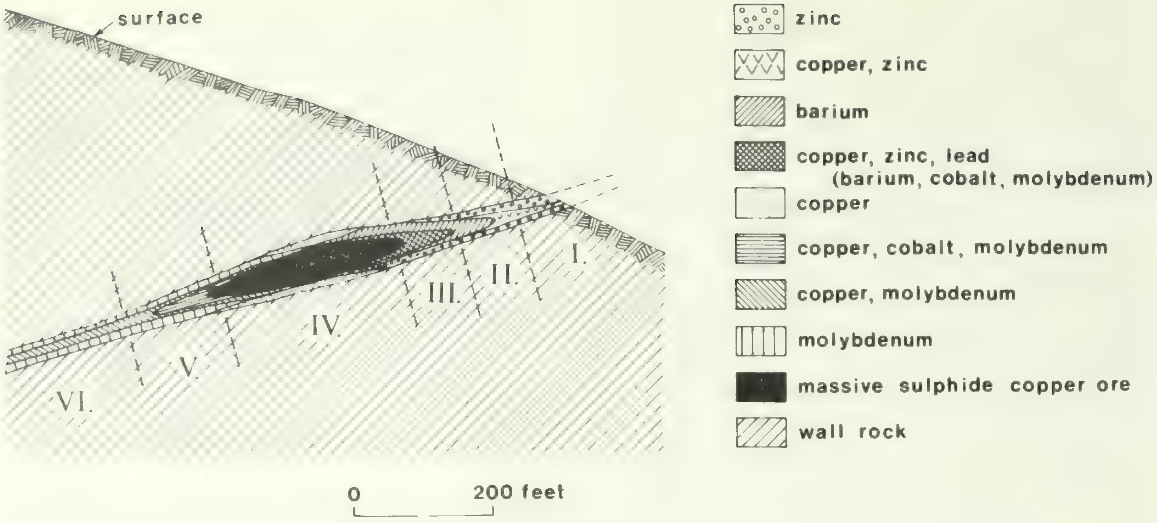
Much rock chip geochemistry is done in the hope that zonal patterns may be discerned, pointing to the area most likely to contain the ore deposit. A very simple pattern of progressive changes, upward and outward from the central portions of the district may be envisioned. A typical zonal pattern for copper veins in the Rocky Mountains, as shown in figure 7, may be quite different than for the zonation of a massive sulfide copper deposit, as shown in figure 8. Many variations of zoning are known for different kinds of ore, and are described in the technical literature. Some companies have done original research and determined their own distribution patterns for ore types of interest, often at great cost. Such privately developed concepts are closely guarded company secrets.

Other than the stone bruises left by the collector's hammer, rock chip sampling leaves no surface disturbance of a permanent character. Rock chip samples are transported from the project area to a centralized company or independent laboratory for preparation and analysis.

Soils

In detailed exploration work, residual soils are usually present, consisting of weathered material derived from the underlying parent bedrock (fig. 9). In many cases, analysis of such soils reveals a pattern of enriched metal values over the suboutcrop of the ore, when no visible float can be found at the surface. The method is far from infallible, and there are many variables that are either highly unpredictable or imperfectly understood. Typically, a few ounces of soil are collected at each sample site, rarely more than a few inches in depth. The sample hole is usually filled in immediately and the site marked by fixing a sample tag to a nearby shrub.

A sample-site or campsite chemical analysis is sometimes employed in soil work, using either the entire sample or only the fine material, sieved for analysis. Soil sampling does not leave signs of visible surface disturbance that remain more than a season or two.


surface
zinc
copper, zinc
barium
copper, zinc, lead (barium, cobalt, molybdenum)
copper
copper, cobalt, molybdenum
copper, molybdenum
molybdenum
massive sulphide copper ore
wall rock
I.
II.
III.
IV.
V.
VI.
0
200 feet

I. Zinc, copper
(lead, barium)

II. Zinc, copper, lead, barium
(molybdenum, cobalt, silver, arsenic)

III. Zinc, copper, lead, barium, silver, arsenic
(molybdenum, cobalt)

IV. Copper, zinc, lead, cobalt, molybdenum
(barium, silver, arsenic)

V. Copper, cobalt, molybdenum
(zinc)

VI. Cobalt, molybdenum
(copper)

Figure 8.--Metal zoning in a massive sulphide copper ore body.

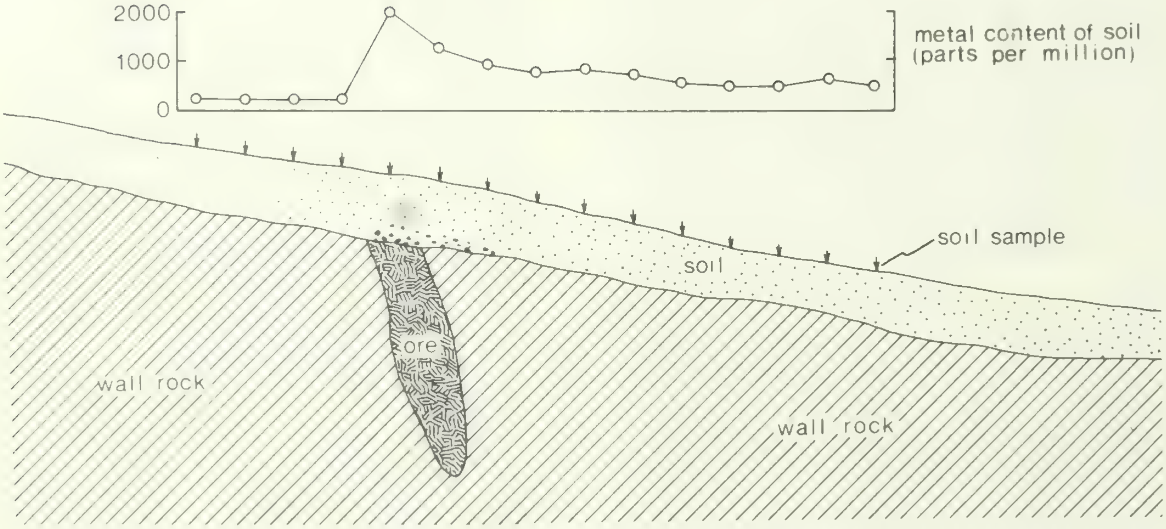


Figure 9.--Geochemistry of residual soil over ore.

Vegetation

The biogeochemical method is used in detailed mineral exploration where the plant material is analyzed to determine trace metal content. The plant may show no external evidence of abnormality. To be useful, the vegetation must be fairly evenly distributed over the area to be explored, and should be known to be a reliable indicator on the basis of experience on similar projects elsewhere or extensive experimentation on the project at hand.

The biogeochemical method has been used successfully where the needles of pinyon have been found to contain unusual amounts of uranium over deposits of this metal. The pinyon, as in the case of a number of other trees and shrubs, has the capacity to selectively absorb an element through membranes in the root system, and to concentrate the element in portions of the plant itself. The roots effectively act as a much larger sampling system than single small handful of soil collected at the surface at one point.

The principal objections to the biogeochemical method are the difficulty in obtaining good samples and the complicated sample processing and analytical techniques. The same part of each plant must be collected if the results are to be significant, and in some cases the sample must be collected at the same season of the year to yield consistent results.

In recent years, biogeochemists have begun to use the mull (granular forest humus) found beneath trees. This partially decomposed material is easy to collect and analyze, and contains a sufficient amount of trace metal to be useful.

Using sampling techniques similar to those used in botanical studies, biogeochemical sampling leaves no permanent marks of damage.

Geophysical Exploration Methods

Some ore deposits contain minerals that possess physical characteristics that can be measured by suitably sensitive instruments. Exploration based on the principles of physics is called geophysics. Exploration techniques utilize such physical properties as density, magnetic behavior, electrical conductivity, and radioactivity. Six basic geophysical exploration methods--gravity, seismic, magnetic, electromagnetic, electric, and radiometric--are commonly employed in the search for minerals.

Gravity

Gravity methods depend upon the relative density of the ore deposit and surrounding wall rock, and are not much used in metalliferous exploration. Measurements can only be made at fixed stations on the ground, and complicated corrections are required for station position and topographic conditions. The typical ore deposit is not dense enough, is too small and irregular, and occurs in a deformed structural environment, making clearly defined gravity anomalies difficult to discern and interpret.

The method has been very successful in exploring for large deposits of petroleum, natural gas, sulfur, and salt. Limited application has been reported in exploration for barite.

Seismic

Seismic methods have little use in metalliferous exploration because of the relatively small size and complicated geology of the typical ore deposit, and because of the high cost of seismic work. The method depends upon the velocities of acoustical energy in earth materials, and has been enormously successful in searching for petroleum, natural gas, and sulfur, where the large deposits may be located by simply determining attitude of the enclosing strata.

Magnetic

Certain minerals distort the earth's field, and where sufficiently large concentrations of such minerals occur, variations can be measured by magnetometers mounted in aircraft, in ground vehicles, or positioned at stations on the ground. Magnetite iron ores have been found in many areas of the world using the airborne magnetometer.

In one case in the western United States, a very large iron deposit has recently been discovered beneath several hundred feet of barren volcanic flow rock erupted over the ore deposit. Magnetic copper skarn, magnetic nickel ore, and asbestos-bearing serpentine associated with certain magnetic intrusive rocks have been found, using the magnetometer. Some geophysicists propose the use of the magnetometer to detect gold placer deposits, because of their common association with black sands largely consisting of the mineral magnetite.

Electromagnetic

Of the various electrical methods of prospecting, only the electromagnetic (EM) system can be used in aircraft. Airborne EM systems have been applied with great success, particularly in reconnaissance exploration for massive sulphide ores on the Canadian Shield.

Electromagnetic methods energize the ground inductively by means of an alternating current flowing in a transmitter coil. The resulting signal, containing ground response characteristics, is detected inductively by a receiver coil. Both coils may be mounted in the aircraft, or both placed on the ground. In one recently developed variation of the method, the transmitting coil is on the ground and the receiver in the aircraft.

The method is relatively slow and expensive, particularly when used on the ground in detailed surveys. It has not been widely applied to exploration in the western United States, where ore deposits generally have poor electromagnetic response characteristics and may be deeply and erratically weathered, further destroying the ability of the ore to respond.

Electrical

Natural electrochemical reactions near the surface of the earth, where metallic sulphides may be subject to weathering, can be used in the simple self-potential (SP) method. The measuring instrument detects the electrical current developed during the weathering of the sulphide, as shown in figure 10.

A shortcoming of the SP method is the frequency and variety of spurious responses obtained. A more popular application of the electrical method is where controlled electrical energy is applied to the earth and the resulting electrical behavior of the ground is observed at closely spaced stations at regular intervals over the surface. An adaptation much used during the past decade is induced polarization (IP) where the conductivity of mineralized ground changes with variation of frequency of the applied current, while the conductivity of barren ground remains constant. As with the SP method, IP often produces misleading results and use of the method has declined recently.

(Measurement of electric current spontaneously generated by a sulphide body)

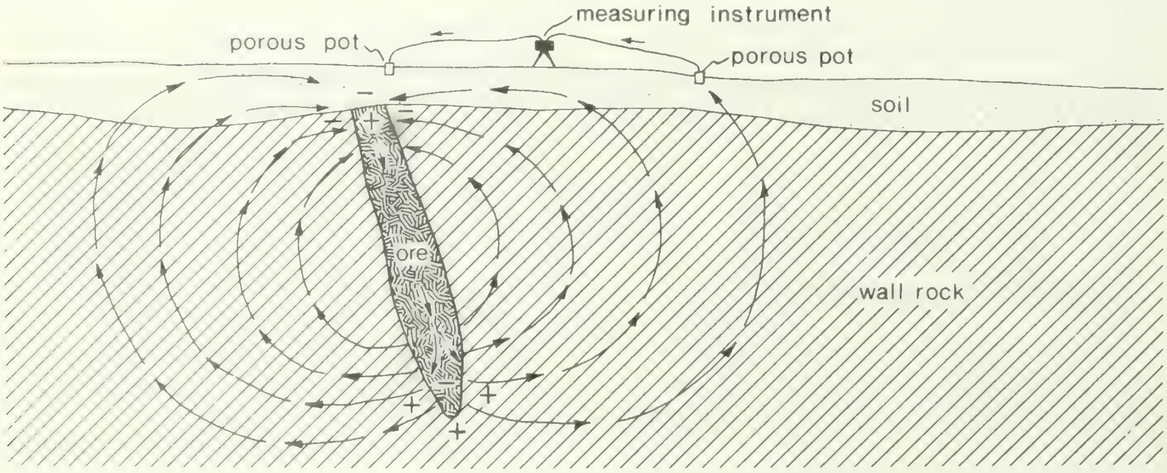


Figure 10.--The self-potential method.

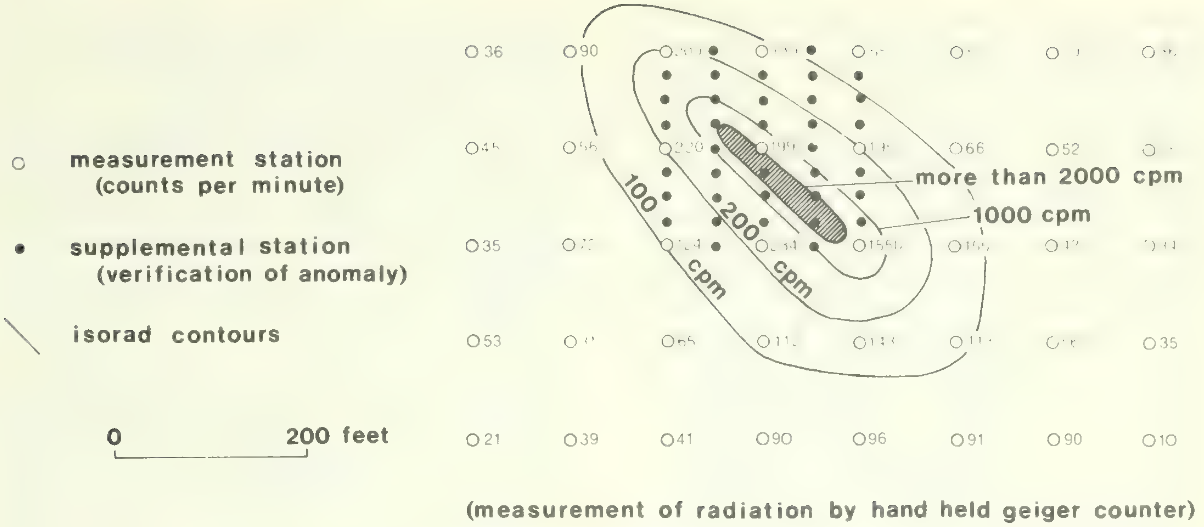

○ measurement station (counts per minute)
• supplemental station (verification of anomaly)
isorad contours
0 200 feet
more than 2000 cpm
1000 cpm
100 cpm
200 cpm
36
90
45
56
220
199
66
52
35
53
35
21
39
41
90
96
91
90
10
(measurement of radiation by hand held geiger counter)

Figure 11.--Plan showing gamma radiation over a uranium ore body.

Radiometric

Uranium, thorium, and potassium occur naturally in earth materials, and being radioactive, anomalous concentration may be detected by radiometric surveys (fig 11). Only gamma radiation is useful in exploration, because alpha and beta emissions are masked by a thin cover of soil, water, or air. Gamma ray emissions penetrate only a few inches of soil or a few hundred feet of air, so that the radioactive ore deposit must virtually outcrop at the surface to be detected.

Geiger counters and scintillometers are easily portable and can be held in the hand, mounted in surface vehicles, or operated from aircraft. Airborne radiometric surveys were successful during the 1950's in exploration for uranium in Colorado, Utah, Arizona, and New Mexico.

Remote Sensing

No ore deposit has yet been found directly by the highly publicized "remote sensing" techniques of exploration from spacecraft. Most of the methods used are adaptations of techniques well known and evaluated in a variety of laboratory, ground station, surface vehicle, and aircraft installations. A tremendous amount of basic scientific data is being collected which cannot fail to be of major value in mineral exploration if properly coordinated with basic geologic concepts and evaluated by personnel experienced in ore search.

Several applications of activation analysis techniques show considerable promise in mineral exploration, and improved versions of instrumentation are becoming available for field use. An intense radioactive source is mounted within lead or paraffin shielding. When the shielding is raised so that the surface area to be sampled is subjected to radiation, some elements respond be giving off a radiation that is measured by a counter within the apparatus. The method might be compared to an interrogation-reply mechanism.

A typical portable instrument can be used only for one element, and the equipment is cumbersome, expensive, and must be operated by trained personnel under Energy Research and Development Agency (formerly Atomic Energy Commission) license. In spite of these shortcomings, limited use thus far has been spectacular in such applications as the search for beryllium ores. Several major deposits of beryllium have been found in old mining districts generally considered to have been thoroughly explored.

Most ore deposits in the western United States do not respond well to any kind of geophysics or are too small and irregular to produce an anomaly sufficiently distinctive to interpret and explore. On the Canadian Shield, the typical ores possess good geophysical response characteristics. Outcrops were scoured clean of weathering effects by Ice Age glaciation, so that weathering does not interfere. The thin layer of glacial drift over much of the region made traditional prospecting methods ineffective, and many ore deposits have been discovered in recent years by geophysics. Canadian explorationists are therefore much more likely to be enthusiastic about geophysical exploration than their colleagues in western North America, who are more accustomed to the complicated, unresponsive, weathered ores of the deserts and mountains.

The geophysical method that might be useful in one area may prove wholly inappropriate in another. For example, airborne scintillation counters were used very effectively in radiometric reconnaissance for bedded uranium ores of the Colorado Plateau in Colorado, Utah, Arizona, and New Mexico. The same technique, when applied to exploration for uranium in Canada, was a total failure. It was found that the Colorado deposits were relatively high grade, and enclosed in a sequence of virtually nonradioactive sediments. The Canadian exploration was conducted in a terrain of granite and metamorphic wall rocks that themselves were radioactive, resulting in such a hash of background signal and false anomalies that the airborne surveys failed to delineate useful target areas within the static.

In general, the most discouraging aspect of geophysical exploration is the spurious result frequently obtained. For example, the ore deposits that furnish the best electromagnetic responses are massive sulphides, which are found in rocks containing variable amounts of pyrite and graphite. The pyrite and graphite, which are worthless and commonly show no meaningful distribution pattern in relation to the ores, yield a geophysical response that cannot be distinguished from that of the ore itself.

Many exploration holes are drilled into electromagnetic anomalies, only to encounter barren pyrite or graphite. Conversely, negative geophysical results by no means rule out the presence of an important ore deposit. For example, the most careful magnetic survey over an "invisible" gold deposit of the kind being found in northern Nevada could not be expected to delineate ore, because these deposits contain no minerals capable of measurably distorting magnetic patterns.

It is obvious that the application of geophysics involves more than the simple ability to make the equipment work. To be successful, the geophysicist must be thoroughly grounded in fundamental ore deposit theory, or must work closely with an exploration geologist in planning and interpreting the work.

Restudy of Old Mining Districts

Only in very unusual cases is it possible to reopen a mine and simply put it back into profitable operation without doing additional exploration or development. Previous mining may have been done in ignorance of a mineral that has more recently become of economic interest, but in general, nothing of value was knowingly left by the oldtimers, or missed by scavengers during the first years after the mine closed.

Today, the exploration geologist reenters old mines and mining districts with an entirely different point of view and approach. He researches old records and undertakes geologic work because the character of mineralization may suggest the presence of an entirely new ore type or because careful analysis of the geology of an old district might reveal new possibilities at greater depths, along a faulted trend, to one side of the old workings, or in some other unexplored situation nearby.

In the study of old districts, great emphasis is placed on geology and mineralogy, because of the wealth of opportunities for inspection and sampling provided by the underground mine openings. Much can be learned from the study of structural control of the previously mined ores. Sometimes, relatively large amounts of money are spent to reopen old workings with the immediate objective only to do geologic mapping and sample the mine.

Perhaps the most discouraging aspect of restudy of formerly productive areas is the effort and cost of land acquisition. Complicated mineral rights such as numerous small patented claims, fractions, lots, former townsites, millsites, tunnel rights, and right-of-way of various kinds make this work very expensive and time consuming. The problem worsens with each new generation of heirs.

Although the typical difficult property situation is offset to some extent by the enthusiasm of working in an area where signs of mineralization abound, the project geologist must gather together enough hard geologic evidence to convince management to proceed with property acquisition before exploration can begin. If the mineral rights to a sufficiently large block of ground in the typical old mining district can be put together on reasonable terms, even for a relatively short period of time, management usually receives such projects with far more enthusiasm than proposals for exploration in virgin territory.

Trenches, Pits, Overburden Drilling

Preliminary exploration work may be undertaken by the conventional prospector, for example, in trenching to establish the trend, width, and mineral character of an ore showing protruding from soil. Many types of ore weather readily at the surface, and these surface effects must be removed if the true character of the mineralization is to be determined. Preliminary trenching and pitting may be done with the idea of making the prospect interesting to the examining geologist and to facilitate his work. Sometimes, the small miner or conventional prospector refers to this as development, but this term is more properly used in connection with the preparation of a mine for production after the presence and general character of the ore deposit is proven.

A large amount of the the surface disturbance on public land is caused when the amateur prospector thinks he has located valuable ground, and begins bulldozing while staking claims. He enthusiastically scrapes into soil-covered areas of any kind with the idea that there ought to be a big mineral deposit in there somewhere. The extreme futility is where such poorly planned trenching is attempted in an area of 50 feet of soil cover. He may often decide to bulldoze crude trails on the ridge lines while the bulldozer is on the property, because in his mind this will improve access and something might be blundered onto in the process.

Prospectors, and company geologists as well, have been heard to remark that they prefer to cut up the land visibly during the act of claim location, so that everyone will know the ground has been staked. Mining lawyers gave this advice for years, prior to the present concern for the environment, and some still do.

This kind of thinking has sharply diminished in recent years, especially where modern State mining legislation has made it possible to locate mining claims without doing physical work on the ground. These new attitudes have already greatly reduced the amount of surface disturbance over the past 5 to 10 years. In a typical western State, tens of thousands of mining claims have been staked annually. This would have amounted to hundreds of acres of surface disturbance under the old location requirements.

In serious exploration by trenching, bulldozers of various sizes are used. Such equipment is easily available and usually is present on the project for other work such as construction of access roads or preparation of drill sites. Mechanical or hydraulic rippers are used in tough ground; drilling and blasting are rarely resorted to because adequate samples can usually be collected at the point where the rock becomes too hard to be moved by blade or ripper.

If additional depth is required in hard rock, a shallow shaft is usually sunk at lower cost and with far less damage to the surface. Where topography permits, the trenches are laid out at an angle to the contour so the bulldozer can more easily dispose of the spoil to one side. The face, or uphill side of the trench, is used for geologic observation and sampling because it is clean of broken material, and survey stakes and sample tags are not knocked down easily by livestock and vehicles. It is normal practice to orient the trench at a high angle, as close to 90° as possible to the trend of elongated bodies such as veins or mineralized beds.

Carefully planned trenching can contribute valuable exploration information, but much trenching is a complete waste of time and effort, for example, in the fairly common situation where the bulldozer operator himself plans the work for lack of good supervision.

Backhoe trenching is becoming more popular in serious exploration work. Good trench wall faces are cleanly and quickly exposed in a variety of topographic and soil conditions, even on relatively flat terrain where the bulldozer would not perform well. It is possible to cut backhose trenches straight down a hillside; in fact, this is the preferred orientation of the equipment for efficient excavation and disposal of spoil.

Surface disturbance is less than with a bulldozer, restoration of the surface is quite simple, and it is possible to selectively place the topsoil to one side and pile the deeper material to the other side so that the trench can be refilled, reversing the excavation process after geologic inspection and sampling of the trenches. It is impossible to exactly restore the surface to original contour, because the excavated material expands as much as 20 percent or more, resulting in overfilling of the trench by this amount. Aside from reducing the surface damage, it is considered good practice to backfill trenches to maintain good relations with other surface users such as holders of grazing permits.

Trenches were often excavated by hand in exploration work prior to World War II. Rising labor costs and the general availability of mechanized equipment make work of this kind too expensive to be cost effective today. Only in extremely remote areas, service by aircraft or pack string, is hand trenching considered feasible. Standard hand tools such as long-handled shovels, railroad picks, pry bars, and brooms are used.

Shallow pits or exploration shafts are excavated where irregular deposits are expected to extend beneath soil cover, or where the alluvium itself is suspected to contain valuable material such as placer gold. Soft, unconsolidate material can be dug with small backhoes to depths of 10 to 15 feet, and circular shafts several feet in diameter can be excavated with septic tank diggers to depths of about 100 feet. Only the uppermost weathered bedrock can be removed by these machines, and if penetration into the rock itself is required, standard methods of shafting by drilling and blasting must be employed.

When shafting is undertaken, it is necessary to securely timber the upper portions of the opening, so that men and equipment can work on the bottom without risk of material falling. Pneumatic drills are usually used, and blasting is done with stick dynamite and standard fuse and blasting caps. The broken material is removed using buckets hoisted by hand windlass, small winch, or power takeoff units on tractors or trucks.

Overburden drilling is a specialized shallow exploration method used to obtain small bedrock samples. The samples are used for geochemical analysis, in geophysical interpretations of various kinds, or for some indirect use, rather than as a prime exploration method where ore itself is the object of the drilling.

Exploration Drilling

Exploration drilling is primarily aimed at determining whether or not the ore target is present, and if so, to obtain a preliminary idea as to its size and grade. Secondary objectives may involve testing general geologic conditions, such as exact type of formation present, wall rock alteration, or geochemical zoning. In the early stages of the work, emphasis is placed on speed and cost, and if preliminary work is successful, a more accurate and more expensive drilling method may be used.

There are many drilling methods, but three--percussion, rotary, and diamond drill--are by far the most common in exploration work. The equipment may range in size and complexity from simple, hand-operated augers to small-scale versions of the rigs used in oil field explorations.

The pattern and spacing of exploration drill holes are dependent largely upon the size, geometric orientation, and internal distribution of mineral values of the particular kind of ore target involved. A clear conceptual model of the particular ore deposit of interest is of great help in laying out an efficient and economic drill hole pattern.

Most deposits large enough and homogenous enough to be mined by bulk methods are drilled with vertical holes arranged in square, rectangular, triangular, or fence (row of holes) patterns, as seen in plan view. Angle-hole drilling is necessary where steeply inclined vein deposits are being explored, and in general is more expensive than vertical drilling.

Hand Drilling

Small, hand-operated drills such as the augers and sample tubes employed in soil test work have limited application in mineral exploration. Although heavy-duty versions of this equipment have been manufactured and equipped with lightweight, aluminum drill rod extensions and tripod hoistworks, these drills are useful only under near-ideal conditions, and cannot penetrate bedrock. The most common limitation is where hard boulders are encountered in the soft soil matrix, or where excessive moisture is found. The principal use of hand drills is in testing abandoned mill tailings, which are finely ground and even grained, and are compacted well enough that the hole will stay open without caving while samples are taken from progressively deeper depths.

Many different kinds of powered augers are used in exploration, ranging in complexity from small, hand-held, post-hole diggers powered by gasoline to the large augers used to set power poles. The most serious limitations are again boulders in the soil, excessive moisture, and inability to penetrate far into the bedrock.

Percussion Drilling

Several of the compressed air drills used in drilling and blasting have been applied to exploration. The hand-held miner's drill, similar in size and appearance to a jackhammer, is sometimes used in collecting small samples in solid bedrock to a depth of about 10 feet. Larger machines, such as the wagon drill used in highway and dam construction, are mounted on wheels and can be towed to difficult drillsites along with an air compressor mounted on a trailer.

Wagon drills, as well as a variety of small track-mounted, self-propelled percussion drills, can drill holes at any angle, often to depths of over 100 feet. The compressed air that powers the drill is also used to cool the bit and carry cuttings away from the face and out of the hole, where they are collected by simple sack holders, buckets, cyclones, or other devices, depending upon the accuracy required of the sample. Percussion drill samples are usually placed in containers and taken from the drillsite for logging and processing for analysis. Large percussion rigs, such as those used in open pit copper mines for blast hole drilling, are too heavy and cumbersome to be used in exploration work. Churn drills, the cable tool rig formerly widely used for water well drilling, are no longer much used in mineral exploration, except for small specialized adaptations used in placer evaluations.

Rotary Drilling

Rotary drills are relatively fast and inexpensive to operate in a wide variety of exploration conditions. Most of the rigs are truck-mounted and completely self-contained, including the air compressor. At higher elevations, auxiliary compressors must be provided, because of the reduced compressor efficiency. Standard tri-cone bits drill a hole 4 inches in diameter or larger, and drill cuttings are blown out of the hole with compressed air. A gasoline or diesel engine drives the unit.

Some of the equipment can be quickly converted for core sampling, although coring is less satisfactory and generally slower than with equipment specifically designed for the purpose. Most rotary drills are mounted on trucks that require relatively good roads. Angle-hole drilling is not possible with most of the rotary equipment available, and is a major limitation of the method.

Because rotary drilling is relatively rapid, samples were formerly piled on the ground in rows, each pile representing from 2 to 10 feet of advance, each row from 20 to 100 feet of hole. In recent years, practice has been to place the samples in containers and remove them from the exploration site, partly to leave a clean drillsite, but also to frustrate competitors' inspection of the drilling results and to permit geologic logging in more efficient conditions at the field office.

With equipment in good condition and a skilled operator, progress of the typical rotary rig will vary from several tens to several hundreds of feet or more per 8-hour shift, and a considerable amount of sample is generated, even using the smaller bits. Rotary drilling is particularly preferred in exploration where the sampling or logging is done "in-hole," as for example where uranium is measured by scintillation probes run in and out of the hole.

Some geologists object to rotary drilling because the samples are broken into small chips and fragments where the structure of the bedrock cannot be seen. Others feel that the relatively low cost and good progress of the method more than offset the disadvantage of the sample obtained, and actually see some advantage to the broken material for inspection and assaying.

Diamond Drilling

Diamond drilling (fig. 12) is generally considered the most versatile drilling method, providing a superior core sample for observation and preliminary testing. The equipment can drill at any angle, including upward from underground stations. Gasoline and diesel engines are most commonly used, although air and electric motors are available. Core recovery is not always good, particularly in mineralized rock, and the method can be painfully slow and expensive. Diamond drillers are usually more experienced and may be more highly paid than other drillers, for the work is more exacting.

Water is usually the drilling medium; compressed air, crankcase oil, or kerosene are used in special situations. The core sample is cut by a circular bit embebbed or set with industrial diamonds. The core passes inside the circular bit face and is collected in a core barrel which retains the sample for removal from the hole. The material ground up by the diamond bit is called sludge, and is carried up around the drill rod to the surface. The core is placed in compartmented boxes and taken to the field office.

In some cases, the sludge is carefully collected and saved as an important part of the drill sample. Sludge is collected in specially designed settling tanks and placed in metal cans for plastic containers for transport to the field office for drying and processing. The clear water is returned for drill use. Where the sludge is not saved, it is allowed to settle out in the bottom of a rude pit called a mud sump, which often overflows on hillside operations leaving an unsightly smear of light-colored drill cuttings down the slope. If drilling mud is not carefully controlled while the work is in progress, and if the mud sumps are not

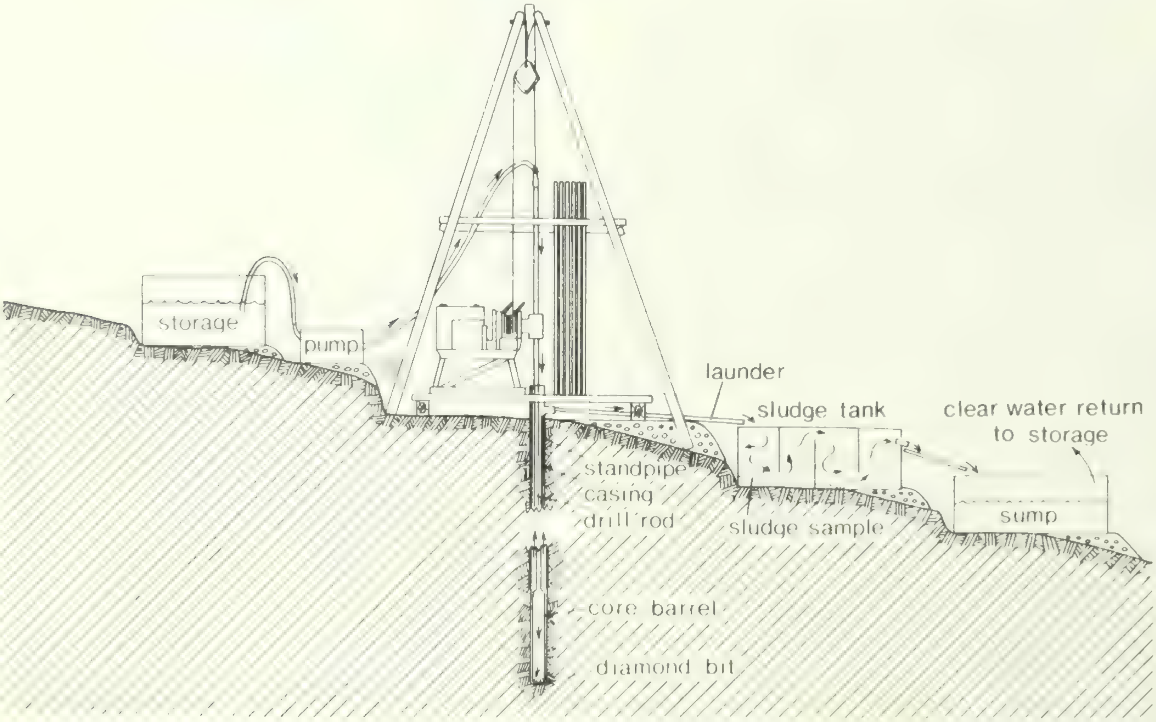


Figure 12.--Diamond drilling, collection of sludge samples.

covered after the work is finished, a particularly unsightly and enduring blemish on the surface can be created.

A variety of additives are placed in diamond drill holes, mostly to eliminate lost circulation, when the drill fluid is lost in fractures or caverns and no sludge sample returns to the surface. Various organic and inorganic materials such as beet pulp, horse manure, and bentonite have been used, along with a number of specially prepared muds developed for use in oil field drilling. Sometimes diamond drill holes are cemented with quickset concrete under pressure, which is drilled back out as soon as it hardens, leaving the hole clean and free of fractures and caves. Sometimes it is necessary to cement after almost every advance of the bit in order to pass through troublesome ground.

Steel casing may also be set in the hole to eliminate caving and lost circulation, and to insure that a reliable core and sludge sample is obtained. By progressively reducing the bit size, and nesting the casing, each smaller size inside the other, it is possible to carry casing fairly closely behind the drill bit. Diamond cores commonly range in size from under 1 to 3 inches in diameter. It is possible to ream the smaller size holes out to accept larger casing, and various combinations of drilling mud cementing, casing, and reaming are used to carry a hole to completion with the desired core size at the bottom of the hole.

In drilling vertical holes in porphyry copper prospects, it is common to cement into the bedrock a short piece of casing called a standpipe, just large enough to receive the largest "N" casing. The casing will in turn accept the NX diamond bit and core barrel, which cuts a hole 3 inches in diameter and a core 2-1/8 inches in diameter. NX bits are used to penetrate the leached cap rock over the ore deposit. As soon as the upper, enriched portion of the sulphide zone is penetrated, "B" casing is set in the hole and the bit size reduced to BX, which cuts a hole 2-3/8 inches in diameter and a core 1-5/8 inches in diameter. After passing through the upper sulphide zone into unenriched ore, "A" casing is set and the bit reduced to AX, which cuts a hole 1-7/8 inches in diameter and a core 1-1/8 inches in diameter.

If deep penetration is desired, far below any level for which mining may presently be planned, it is considered permissible to make one further reduction by setting "E" casing and proceeding to the termination depth with EX bit, the smallest used in most American mineral exploration. EX bits cut a hole 1-1/2 inches in diameter and a core 7/8 inch in diameter. Such a sample is usually considered too small to be reliable in serious evaluation of large bulk mining situations. Upon completion of the hole, the steel casing is removed to be used again, for it is very expensive.

Underground Exploration

Only in rare instances is underground exploration the prime method of proving a prospect. A small, well-defined exploration target such as a faulted segment of a vein might be most efficiently explored by extending old underground mine openings or from new work from the surface, but in general, a certain amount of drilling is done first to at least roughly outline the ore target.

Underground work is usually erroneously referred to as tunneling. Tunnels are seldom excavated in mining, being a basically horizontal opening from one side of a mountain to the other, as in railroad and highway construction. The American metal miner refers to horizontal work into a hillside as an adit (fig. 13). If the adit is driven along an ore structure such as a vein, this is called drifting and the opening is referred to as a drift. If the adit cuts across the wall rock at an angle to the structure, it is called a crosscut and the work is referred to as crosscutting. The mouth of the adit opening is called the portal. Work upward from the adit level is called raising, and the working is referred to as a raise. If the excavation is downward, it is called a winze. Raises and winzes are usually in ore, although the same terms are used whether the work is in waste or in barren wall rock.

A shaft is a vertical or steeply inclined opening excavated from the surface. The term "inclined shaft" refers to openings inclined from vertical to 45° or less. When the inclination is gentle enough to accommodate a man on foot, rubber-tired equipment, or conveyor belts, it may be referred to as a

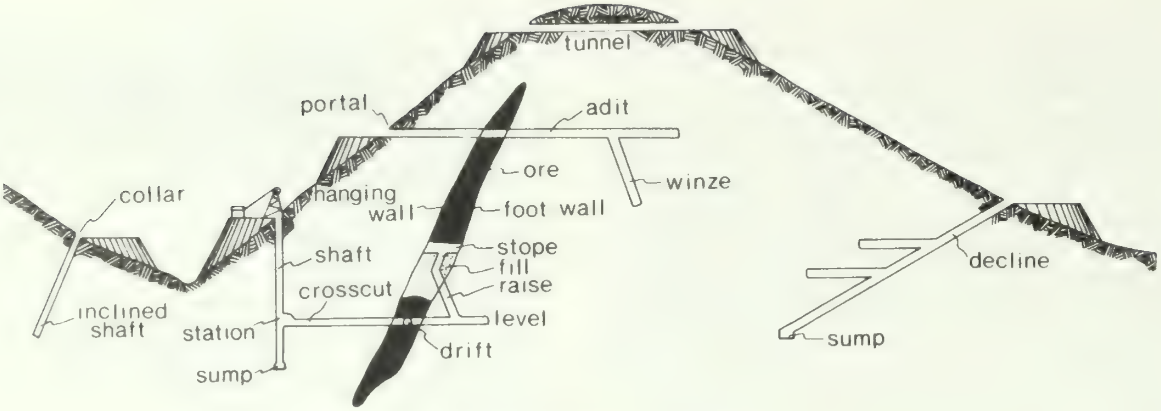


Figure 13.--Underground mining terms.

decline. Shafts, inclined shafts, or declines may or may not be in ore.

If work is undertaken underground from the shaft, a station is cut as a landing for men and equipment, and horizontal work from the station is by drifting or crosscutting, and is referred to as a level in the mine. Work on any mine level is generally inclined gently upward away from the shaft station, so that any water encountered will be drained toward the shaft where it can be pumped to the surface or diverted to an inactive portion of the mine.

The methods and terminology used in exploration work are the same as in standard mine development, but the openings are often driven in smaller cross sections to economize. They can later be enlarged if they are to be used for ventilating or draining a productive area, or in the movement of personnel, equipment, or ore. Excavation is usually by drilling and blasting, although soft or highly fractured ground may slowly yield to advance by "pick and poke" methods, using nothing but a steel hand bar.

Drilling is done with pneumatic drills, and compressed air furnishes the power for the drill, provides air to the men at the working face, and moves powder smoke from the heading after the blast. Holes are usually blasted with stick dynamite and standard caps and fuses. Electric blasting is sometimes used as it is safer and is more efficient than spitting each fuse separately. The material broken at each blast from the face is called a round and the material itself referred to as muck. A muck plate or slick sheet of flat steel is sometimes laid on the floor before blasting to facilitate shoveling or mechanical loading of the muck into wheelbarrows or mine cars and removal to the surface by tramming.

If some of the broken material removed from the mine is known or suspected to be valuable, it is placed on a separate dump. It is quite common to find small dumps at exploration adit portals separated into two, three, or even more separate portions. Careful sampling may reveal little of value in the separated material.

Small, rubber-tired machines are now available to load and tram from working face to portal, eliminating the need for rails in modest exploration programs underground.

In former years, it was possible to find miners skilled in the art of hand drilling or single jacking, the striking of hand steel with a short-handled heavy hammer called a single jack. Such work could be done without air compressor, air lines, or heavy drills.

Small, portable gasoline-powered drills have limited application in exploration work, and there is constant danger of carbon monoxide even in the shallowest of excavations.

Today there is a prejudice against underground work as a prime exploration method, and usually underground openings are not thought of as exploration work. Exploration is usually equated with drilling from the surface, and any mention of underground openings suggests that the work has somehow progressed to the development stage, and that the presence of ore is no longer in question.

Bulk Sampling

In most exploration work there is a need for large, representative samples of the ore deposit. A final cross-check of the grade of the deposit must be made, as well as testing to determine the best choice of metallurgical method. Bulk sampling may also yield other valuable data of use in planning mine and haulage facilities, the treatment method, or disposal of waste.

The mining characteristics concern such factors as the way the rock in an open pit mine may be expected to break during blasting and to support itself on a bench face, and the manner in which the rock will cave in an underground block caving operation or support itself in an underground mine. Metallurgical treatment methods can be most effectively researched by pilot testing techniques, and disposal of waste can be carefully researched using the waste from these original testing programs.

Because of the large amount of material required, bulk samples are usually collected underground. The undesired surface chemical and physical effects of weathering can be avoided, and there is less problem in controlling fly-rock when large samples are broken by blasting in confined underground openings.

In most cases, bulk sampling produces a larger volume of material than can be readily handled. A temporary sample plant is constructed at the site to reduce the size of the sample, yet retain its representative character, particularly as utilized for a final check of grade and in pilot scale mill testing. It is sometimes desirable to prepare a representative sample for prospective purchasers of the mine product.

In a typical situation, the mine-run material, blasted and mucked from individual rounds of underground advance in designated test areas, is moved to a primary surface storage bunker with a 10- to 50-ton capacity. Each round is stored separately and assigned a lot number. As each lot is removed by front end loader and transferred to the crusher, the bunker is carefully cleaned to prevent loss or buildup of fine particles of the economic minerals. The total storage area accommodates 2 or more days of mine-run material.

A portable crushing plant with a primary jaw crusher, secondary crusher, and a vibrating screen system produces a 1/2-inch mill feed product. Conveyors and transfer points are covered to reduce dust loss. The 1/2-inch product is sampled with a sample cutter producing 400 to 500 pounds per hour of sample for testing. The material is fed to a tertiary crusher producing a 10-mesh product, from which a 5-percent "split" is taken. This splitting procedure produces 20 to 30 pounds per hour, which is bagged and sent for assay. The remainder of the crushed bulk sample is fed into a pilot plant.

Samples obtained from most exploration drilling are not completely satisfactory in preparing representative bulk samples. The small samples are too finely ground by the drill, and in other ways rendered unreliable as a sample for investigation of breaking, handling, and processing characteristics.

Typically, large-scale bulk sampling is undertaken in the last stages of exploration of a low-grade ore deposit to be developed by open pit methods. At one porphyry copper property, a shaft was sunk on a centrally located portion of the drilled-out deposit in mineralization believed typical of the ore body. The shaft was sunk directly on one of the exploration drill holes, and all the material excavated was collected as one hugh sample. A station was cut in the shaft, several hundred feet below the surface at about the level of the lowest open pit mining planned. From the station, drifts were driven radially outward in a pattern resembling the spokes of a wheel, each drift directed toward an adjacent exploration drill hole. A raise was driven on each of these drill holes, using it as a pilot, to the surface.

The material from each of the raises was separately stored as an individual bulk sample. Each sample was separately processed, and the grade of copper was analyzed as a check against the assays obtained in the original exploration drill holes. A very small upward revision of the drill hole assays was indicated, lending confidence to the enterprise, and adding millions of pounds of copper to the ore reserve available for mining.

Pilot Testing

Preliminary metallurgical "bench tests" are performed using a few hundred pounds of ore from the drill core. The tests provide a general idea of the milling procedures to be used in concentrating the ore.

In a major project, underground bulk sampling provides sufficient ore to operate a pilot plant with a capacity of 50 to 100 tons per day for several months. The pilot plant is a miniature version of the full-scale plant to be built to concentrate the ore from the mine. The design of the pilot testing plant is based on knowledge of the type of ore in the deposit and the details of bench testing of ore from exploration core drilling.

Details of crushing, grinding, concentration characteristics, and waste disposal can be studied over a period of time in a pilot plant. Also considered are the effects that a change in one part of the process will have on another, as well as the overall efficiency of the process. Alterations are made in the design of the full-scale plant. Costs of construction, operating costs, and waste disposal problems can be determined for use in broad planning and in the final feasibility study.

On a large project, the pilot plant work may be done in a plant specially constructed at the mine site. In other cases, pilot test work will be done at a central company laboratory location, university facility, or by metallurgical research companies specializing in this work. The small operator usually conducts pilot testing on a very small scale, and anticipates months of modification of his full-scale plant to insure good results.

Feasibility Studies

At some point in the continuing exploration, it may become apparent that the program is successful--that an ore deposit is present. Then begins the work of bringing the ore body to its full potential by developing enough ore to plan a mining operation, or to completely explore and develop the entire deposit.

In a typical feasibility study, all of the information gathered earlier is assembled and turned over to an engineer or engineering group for evaluation. While this study is underway, exploration continues as the project geologist tests the various possible extensions of the ore body.

Once the decision has been made to begin development, the exploration geologist or prospector, who has largely been responsible for finding the ore body, leaves the scene. For a variety of reasons, the exploration geologist or prospector no longer contributes effectively to the process of making the prospect into a mine. Further geological work, drilling, or other operations to block out ore are done by a mine geologist under the supervision of local mine managers, who are, of course, production oriented.

The formal feasibility study includes an economic analysis of the rate of return that can be expected from the mine at a certain rate of production. Some of the factors considered during such an economic analysis are:

Tons in the deposit
Grade of the mine product
Mill recovery
Sale price of the metal or mineral
Cost of mining per ton
Cost of milling per ton
Royalties
Capital cost of the mine
Capital cost of the mill
Exploration and development cost
Mining rate, tons per day
Depreciation method used
Depletion allowance
Working capital necessary
Miscellaneous costs of operation
Tax rate

In many cases this information will be put through a computer to calculate the dollar value of the yearly gross sales, operating costs, operating income, depreciation, depletion, income tax, net income after taxes, the cash flow and the after-tax rate of return on investment. Many companies have their own programs and computers. Outside firms are available to undertake this work for a fee. Prior to the advent of computers, this information was laboriously calculated by a team of engineers using mechanical equipment requiring hundreds of computations and days or weeks to complete the analysis.

Each mining organization has a minimum acceptable rate of return on investment. The cost of borrowing capital for the mine or of generating the needed capital internally within the company must be considered. If a company has a number of attractive investment opportunities, the rate of return from the proposed mine venture may be compared with the rate expected on a different mining venture elsewhere, or with some other business opportunity unrelated to mining. Every organization has a limit to the amount of funds available for new capital investments. Management has an obligation to its stockholders or investors to select projects with the best rate of return.

As a general rule of thumb, a project must have better than a 15-percent rate of return to be considered by a major company. An individual commonly expects a 30- to 50-percent rate of return to consider investing in a mining venture. Among other uses of the cash flow generated by the mine, these funds must finance continuing exploration elsewhere, pay for past failures, and contribute to the mine's portion of main office and general overhead.

DEVELOPMENT

After exploration has provided a rough idea of the shape and size of an ore deposit, general geological characteristics, and average grade, and feasibility studies have thoroughly analyzed the data available, the decision to develop the property may be made.

At this time, the owner may decide to obtain outside financing. Standard loan financing is not often available to mine developers. The property may be sold outright for cash or for stock in an operating company, or a royalty on production may be retained. The owner of the new ore deposit may attempt to interest an operating group in furnishing management and undertaking operation of the mine for a percentage of the return. Often some form of joint venture is worked out, when the owner of the ore deposit will agree to share the profits after the mine has been put into production with an operator who is to provide the capital and know-how to develop the mine. Even when the company develops its own exploration find, there is need for careful development planning because capital investment is large, and mistakes are costly from this point onward.

There are almost always small bothersome details remaining at this point that should have been attended to prior to the discovery and outlining of the ore deposit. For example, a suitable millsite or townsite might not have been secured, minor property ownership problems may need to be resolved, or water rights may not be secured. For this reason, and the fact that entirely new personnel are sent in to undertake development and may not be fully familiar with all aspects of the program, company personnel are just as close-mouthed as ever in dealing with outsiders.

The various methods involved in mine development, and the emphasis given to them, depend to a large degree upon the kind of ore body involved and the mining method to be used. Some of the more common approaches to mine development will next be described to provide insight into this poorly understood aspect of mining.

Drilling Large Deposits

One or more stages of exploration drilling, perhaps done over several decades, may reveal the presence of a large body of what can now be called ore, considering present technology, economic conditions, and metal prices. The entire deposit, or selected portions of it, may now be drilled carefully to determine its exact grade, volume, and three-dimensional outline. The development program should furnish the following information:

1. The size and shape of the ore deposit.
2. The average grade of the deposit and total tonnage of material that can be called ore within prescribed economic limits.
3. The distribution of different kinds of ore, and the mineralogy of ores, if more than one kind will necessitate separate handling or treatment.
4. Geology of the ore body, particularly as it will affect mine design and layout.
5. The location of waste rock which must be selectively cast to one side or left unmined.
6. Operating factors such as ground water, nature of the rock as it may affect blasting or ripping characteristics, bench level intervals, pit slopes, and need for secondary blasting.

The pattern and spacing development of drill holes requires special care because first preliminary ore reserve calculations are based upon the drill hole sample data. Some bulk minable types such as iron, coal, phosphate, and potash usually have relatively uniform distribution. Low-grade copper or molybdenum mineralization is much more erratic.

Statistical techniques are important in planning development drilling programs, and in the analysis of the sample data obtained. Enough holes must be drilled to insure continuity of geologic data between drill holes and to assess the relation of geology to grade changes.

Where mathematical procedures have been used in determining the layout of development drill holes, it may be necessary to adhere to a relatively rigid geometric pattern or interval between drill holes, and this may require preparation of drill sites in positions that would normally not be considered, at least in the initial phases of exploration work. The drill roads and drill sites are often better designed and more elaborate than for exploration, because the equipment to be used is more complex and will be in operation over a longer period of time, and work continues the year around except in areas of extreme seasonal weather conditions.

Drilling Small Deposits

If exploration of a small irregular deposit indicates the general position of the ore deposit in the subsurface, and if a high enough grade or large enough tonnage is indicated, there may be a trade-off decision whether to undertake more drilling, perhaps using more precise methods, or to proceed directly with a limited amount of underground development. This usually depends more upon the philosophy of management than on the facts that might be presented; some production and exploration managers prefer to drill, and cannot conceive of underground work for anything but production.

Usually the decision to continue drilling is made where costs are reasonable and there is total confidence in the sampling procedures. If the deposit lies near the surface and can probably be mined by open pit, there is merit in a grid of vertical drill holes to exactly define the limits before stripping waste or attempting initial mine production.

There are many cases where bold exploration drilling programs have been conducted in areas of small, erratic, high-grade ore deposits. In one such district in mountainous terrain, 10 relatively deep drill holes were put down in an old silver district, and 3 of the holes intersected mineralization suggestive of the ore mined in the past, but at scattered localities, at least 500 feet vertically, and 2,000 feet horizontally from any point where underground development might begin. The costs of further drilling, of shafting, or driving an adit were all far more than any profit that could reasonably be expected from an average ore deposit in the district. The question in a case such as this becomes not so much "what do we do with it?" as "why did we get ourselves into this dilemma?"

As in all phases of prospecting, exploration, and development, the prime function of the project geologist is to have a clear picture of the exact kind of ore sought, and the possible size and grade of the ore deposit as an economic entity.

Development Shafts and Adits

When the decision is made to do a certain amount of underground work as the first step in mine development, it is essential to have the plan for mining worked out. In hilly or mountainous terrain, planning is less critical because a few short adits and a raise or two (fig. 13) to the surface will inexpensively begin the development of the ore deposit and be of major value later in ventilation and in movement of men, equipment, ore and waste rock. If the terrain is relatively flat the decision to proceed is far more critical, because shafting is very expensive, and only a vertical shaft, well situated with respect to the ore deposit, will be useful during later production work. If enough data are not available to plan such work, one might seriously ask if exploration information is sufficient to proceed with development.

It is not uncommon for mines to go through two or more stages of development and redevelopment. A relatively modest shaft and hoisting facility might be entirely adequate to develop and mine 100 tons of ore per day in relatively rich material near the surface. After several years, long-term plans may indicate the need for a much larger headframe and hoist, when development of large tonnages of low grade ore deeper in the mine makes possible a production rate of 1,000 tons per day with a new and larger mill on the property. The smaller operation may have financed the major development work, and proven the larger ore reserve far more thoroughly than any exploration work that might have originally been justified. Usually these redevelopments are not intentional but are the result of higher metal prices, unexpected good results in initial development, new milling methods becoming available, or other factors.

Blocking Out Ore Underground

In a typical underground operation, it is desirable to postpone some of the development work until after the mine is put into production. In this manner, capital investment requirements are offset as some financial return begins to come in. In the United States it is common practice to develop and produce from the upper levels of a mine, and to later deepen the shaft and develop the lower levels in a carefully planned schedule timed in coordination with depreciation of the surface plant. Usually some rule of thumb is adopted to insure that a ton of ore is developed for each ton of ore mined.

At one property, a foot of development (drifts, raises, winzes) might be done for each 10 tons of ore taken from the mine. At another property a foot of diamond drilling per ton of ore may be crude insurance that the development of the property is a viable operation.

The yearly statement of "ore reserves," if made available in any form to outsiders, therefore does not accurately reflect the possible ultimate production of the mine. There are many reasons for such conservative practices; abrupt fluctuations of metal prices can convert ore to waste overnight, local tax laws may be applied on an "inventory" basis to a wasting asset, labor negotiations can become difficult if there is a false impression as to longevity of the operation, and there would be legal questions introduced if speculative material were called ore by management.

When a miner speaks of production plus reserves, he is making little allowance for ore that lies far ahead of present development work. Some companies have only a certain minimum tonnage of reserves on hand, and do not feel the cash required to increase the reserve figure is a good investment. Three categories of ore--proven, probable, and possible--are generally accepted in statements of ore reserves (fig. 14).

Proven (Measured) Ore

Proven ore is that for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, or drill holes, and for which grade is computed from adequate sampling. The sites for inspection, sampling, and measurement are so closely spaced, on the basis of defined geological character, that the size, shape, and mineral content are well established.

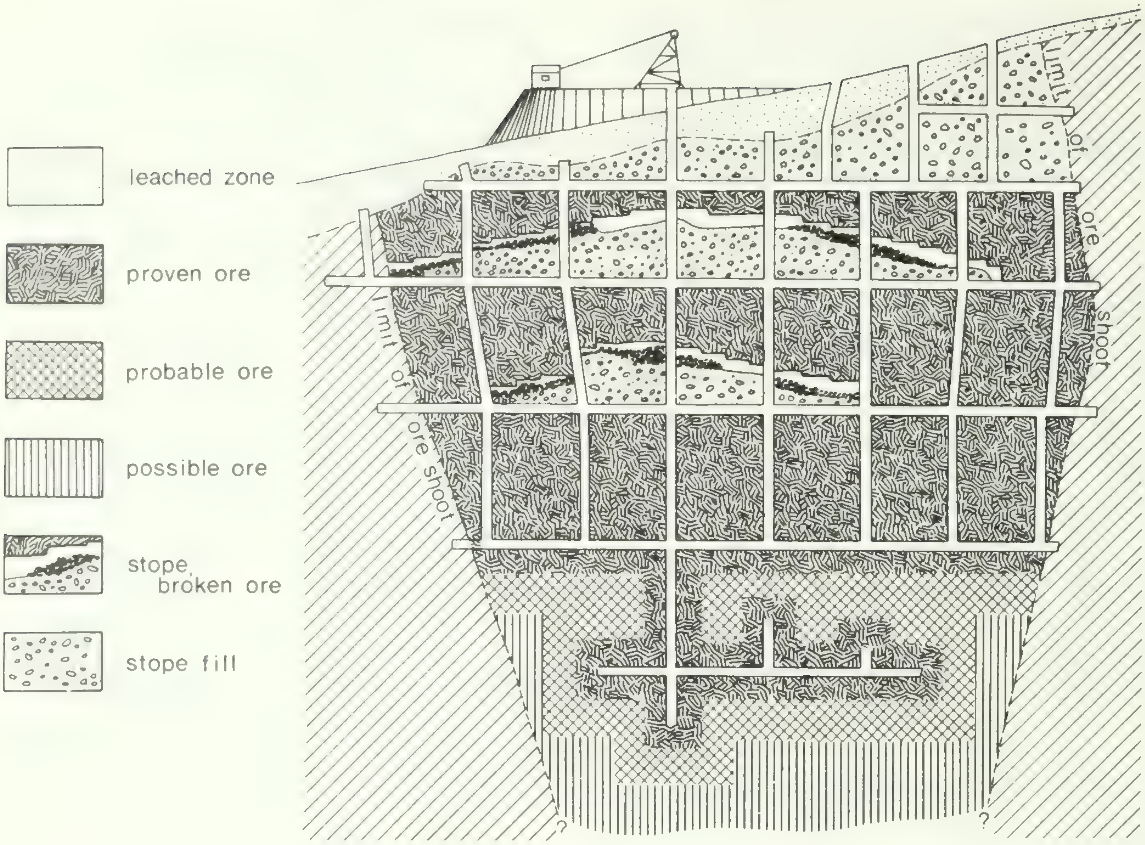


Figure 14.--Partially developed vein, three ore categories.

Probable (Indicated) Ore

Ore for which tonnage and grade are computed partly from specific measurement, samples, or production data, and partly from projection for a reasonable distance on geological evidence is considered probable ore. The openings or exposures available for inspection, measurement, and sampling are too widely or inappropriately spaced to outline the ore completely or to establish its grade throughout.

Possible (Inferred) Ore

Quantitative estimates of possible ore are based largely on knowledge of the geological character of the deposit and few, if any, samples or measurements. Estimates are based on assumed continuity or repetition for which there is geological evidence; this evidence may include comparison with deposits of similar types. Bodies that are completely concealed, but for which there is some geological evidence, may be included.

The terms proven, probable, and possible are used by mine operators to distinguish the ore categories in a single mine or perhaps, at most, a mining district. Locally, much more rigorous definitions of proven, probable, and possible are used. The terms measured, indicated, and inferred are applied in a much broader sense, such as in expressing the reserves of the bedded phosphate ore in a western State, and are employed mostly by Federal and State agencies, mineral economists, academicians, and commodity analysts.

Access

Because of the heavy flow of traffic and large equipment involved, the requirement for good access roads is generally greatest during mine development. Many western States and counties move construction and maintenance of improved roads into a position of first priority in their budgets, especially where a good road can be easily constructed from one of the county's towns directly to the mine. The county then not only receives the tax benefits provided directly by the mining operation, but also retains the much larger secondary benefits of commerce and employment and tax revenues from them. The tremendous economic impact of a new mine operation is often not fully appreciated by economists and land use planners more accustomed to dealing with agriculture or normal urbanization, and the financial impact may come as somewhat of a bombshell to local planners.

The access roads to a property being developed by underground methods are often in canyon bottoms and stop at the site of the main shaft of adit portal on the main development level. Additional roads over the surface of the ore deposit are not usually necessary, except to service ventilation equipment in a second exit or for other service functions specific to the site.

Where large deposits are being developed by drilling and open pit methods are planned, building access roads for drills is a major undertaking, and surface disturbance is at a maximum, especially in the area immediately over the ore. These roads can be extremely unsightly because they are so closely spaced and often traverse steep hillsides where no normal road would be planned. They will be removed during stripping and mining or will be covered by waste dumps placed around the pit as development and production continue. In general, the access roads on private property will be paid for entirely by the mining company, although they may be later opened to provide access for the public to recreational areas, vistas of the mine operation, or other areas of general interest.

Power

The requirement for electricity in mining operations is usually large from the development stage onward where essentially all power is electrical except for mobile units, such as trucks. Large developments usually involve contracts with power companies and public utilities for new transmission lines and substations necessary to bring outside power into the property. At smaller properties, or those in very remote locations far from low-cost sources of electricity, diesel generator sets are installed within the mine-mill plant complex. The principal considerations are a site suitable for unloading and storage of bulk fuel, distance of transmission of power, and position of the plant away from residential areas because of the noise.

Energy for the powerplant is usually derived from water or hydrocarbon fuels in typical mining situations. The diesel-engine generators especially adaptable to smaller locations have outputs up to 15,000 to 20,000 kilowatts and can be preengineered by manufacturers to company specifications. Steam generating plants generally have a minimum economic output of 5,000 kilowatts. Where public utility or Government power is available, the mine owner usually finds it cheaper and more reliable than generators, and he will share in the cost of constructing the connecting line from the closest existing utility line. Up to a connected load of about 1,000 horsepower, it is cheaper to let the utility provide a primary substation; above this horsepower a more favorable rate may be obtained by constructing a private primary substation to transform incoming power to usage voltages.

Communications

At most locations, entry into the development stage calls for planning full telephone communications for the mine and mine community. In the western United States, mine operators are not as aviation conscious as in similar areas of Alaska or Canada, but some thought is usually given to a small landing strip or helicopter landing area for direct air evacuation of seriously ill or injured personnel.

As development continues, limited medical facilities are constructed, but the nature of mine and mill industrial accidents is such that immediate air or other rapid evacuation of victims is contemplated to the specialized medical facilities available only in the larger communities. Many companies maintain company-owned ambulances or enter into contractual or cooperative agreements with others for ambulance service.

Site Preparation

The location of the ore deposit determines the mining method, and once the choice is made, the siting of surface facilities is a relatively inflexible analysis or checkoff to determine which location best meets requirements.

Mine

If a vertical shaft is to be the main development, it may be desirable to sink it in barren wall rock at one end or to one side of the ore deposit to keep haulage and hoisting facilities clear of actual underground mining, yet minimize tramming of ore underground to the mine exit. Inclined shafts and declines allow a measure of flexibility, for they can be directed from a suitable surface point to the ideal position underground.

Horizontal development by adit is the most difficult to plan in some respects, and is usually considered only where topographic relief is considerable. Development by adit is preferable because water can be drained without pumping, and level ore haulage systems require far less energy and capital investment than hoists over shafts or conveyor systems in declines. Also, the ore and waste can be taken down and out of the mine at minimal operating cost.

The mine plant must be suitably situated for access by road. The ground beneath must be suitable for support of building foundations, and the area should be free from risk of landslides, avalanches, or unusual runoff during the various flood seasons.

The basic mine plant for underground mining operations consists of headframe, hoist, timber framing and storage area, miner's change house, compressor house, machine shops, warehouse, office, ore storage, and ore loading and shipping facilities. In unusually severe topography, the ore may be hauled by truck, conveyor, or aerial tramway to the treatment plant, and coarse crushing may be done at the mine. Normally the ore treatment plant is placed as close to the mine as possible to reduce handling, and in some cases to facilitate return of the mill tailings underground as fill to support stoped areas (see fig. 13, 15).

In many underground mining situations, the surface plant can be located directly over the mine without fear of damage due to subsidence. Where large amounts of development must be done in barren wall rock, and the resulting waste cannot be disposed of in cut-and-fill stopes, it is necessary to provide for waste dumps near the collar of the shaft or portal of the adit.

In open pit operations, large areas are required for roads, mining, stripping, disposal of waste rock, and low-grade stockpiles or heap leaching operations.

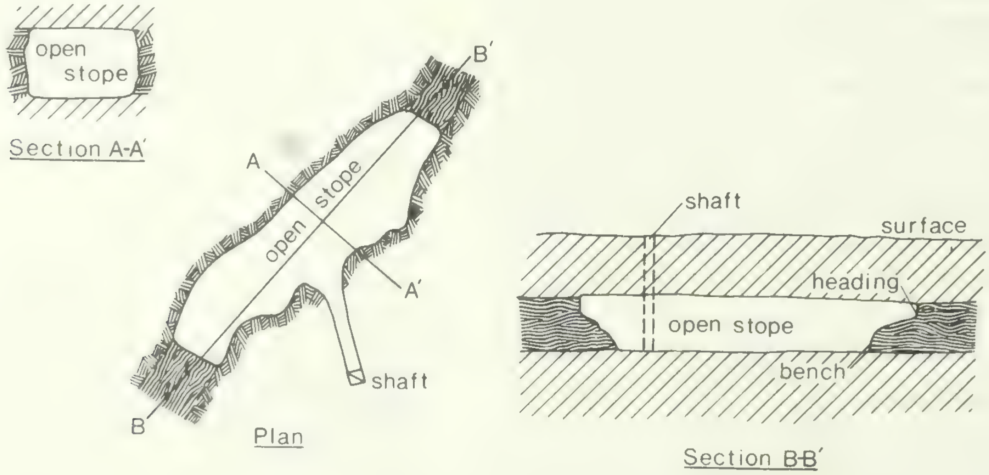


Figure 15.--Open stope mining method.

Extensive parking areas are required if the employees travel to work by automobile. When space is restricted, remote parking areas are serviced by shuttle buses to take the men to the working area. If the mine is in a very remote region, temporary housing and meal facilities may be provided for visitors, maintenance personnel, and top management.

An effort is usually made to locate and construct the mine plant in harmony with the local environment, but safety and fire insurance considerations may dictate a certain amount of careful clearing of forest around the surface installations so that they may be protected from forest fires. This also minimizes the risk of igniting the surrounding forest if a fire starts within the plant.

In extremely difficult surface situations, mine plants, and in a few cases the ore treatment facilities, have been installed underground as a more economical measure than attempting to combat steep terrain, bitter low winter temperatures, or risk of avalanches. Today much consideration is given to locating the surface mine plant in some side canyon away from public view, even if this may involve a longer haul for ore and waste and extended access roads. With planning and a slight additional investment, it might be possible to have the entire mine operation out of sight of the average tourist.

Mill

In former years, mills were generally constructed on hillsides to utilize gravity to feed ore and water through the plant. Today, construction costs and workers' demands favor construction of mill facilities on about the same level as the mine. The mill is situated at some convenient site between the mine and the mill tailings disposal area. The main offices and powerplant are usually located at the mill, where mine and mill are separated.

Ore crushing, blending, and storage units must be accommodated, as well as the mill structure itself and warehouses, loading, unloading, and weighing facilities. Loading and turnaround facilities for trucks and railroads may be a major space requirement, where large amounts of ore or concentrate are shipped or large quantities of mine supplies and mill reagents are received.

Townsite

Whenever possible, mine planners try to avoid getting into the business of providing housing, public buildings, streets, schools, and playgrounds. They will make every effort to utilize and expand existing facilities in nearby towns. The idea held in former years that an additional profit could be made from the company store and other tightly controlled facilities has given way to an open attitude where the company will help support local schools, trailer parks, and medical and other facilities, with private individuals or independent groups responsible for their operation.

Where a town is built for company personnel, suitable space must be provided for a small city in no way different from a mature community, except that all applicable building codes will necessarily be adhered to and the facilities commonly serve a larger proportion of younger families. The townsite may be close to mine and mill, so close that the average employee can walk to work. The housing provided for families usually is an added cost of the operation, but living facilities for unmarried workers may come much closer to breaking even financially. North American mining communities average about five persons per family, and the ratio of married to single employees varies depending upon the isolation of the project.

In extremely remote situations, unusual schedules are established so that employees work relatively long shifts for short periods, with high wages and frequent short vacations, and free transportation home to their families and back. At the mine, bachelor facilities are provided for all workers. The operation is expected to yield a higher than normal return on investment to offset these increased labor costs.

Postponement of Production

Sometimes, after the excitement of the original land acquisition and exploration drilling, work on a mine project is halted. This is perplexing to local people, some of whom may have begun to make changes in their personal and business lives in anticipation of the new mining operation. There are many reasons why a mining company may delay putting property into production. There are always rumors going around when this happens, and business people and community leaders sometimes call for a clear statement of intent, so that everyone will know what to expect.

Sometimes it is possible to make such statements, and periodic updates may be issued in the interests of community relations. Just as often, company management has been so taken aback by an unforseen or uncontrollable event, or series of events, that they do not know what the best plan for the future might be. Rather than issue a false statement, or speak in generalizations tantamount to falsehood, the company may choose, or be advised, to remain silent. The local project manager sometimes has no authority to discuss the future of the project, and a meaningful statement can only be obtained from higher management.

Although there are cases when a company may decide to delay further development, it is not usually advantageous to do so. A considerable capital investment must then lie idle, providing no income. Such items as the wages of standby personnel and watchmen, costs of insurance, taxes, minimum payments on property, and assessment work on claims add up to a major expense and accomplish nothing productive. The morale of project personnel is also a consideration; professional staff prefer to be associated with a live project, where a sense of accomplishment can be gained from the day-to-day activities of a successful operation. To the individual professional person, assignment to a dormant project often translates into a dormant professional career.

Some typical reasons why a company may decide to delay production are: (1) A portion of the mining property, water rights, surface rights, or other legal rights still has not been acquired; (2) better market conditions may be anticipated; (3) equipment or personnel may be coming from other operations; (4) an assortment of unrelated problems might best be solved by simply waiting them out.

Many and varied are the reasons why a company cannot put the property into operation immediately, and some of the more critical ones are completely beyond the control of the company:

1. Drop in price of mine product, or no rise in price if this had been anticipated.
2. Increase in labor costs.
3. Unfavorable legislation or regulations.
4. Change in tax laws or assessment procedures.
5. Threat of litigation.
6. Action of private conservation groups.
7. Lack of smelter or refinery capacity.
8. Lack of capital.
9. Delay in obtaining delivery of major equipment.
10. Lack of transportation facilities.

Although one or two of these considerations, or similar ones, may be the paramount reason for postponing development of the mine, there are usually many other factors involved, and the "go" or "no go" decision is carefully weighed against a list of favorable and unfavorable factors, some of which may be changing while the deliberation is being made.

From the standpoint of surface damage to the environment, it is particularly unfortunate when the property must be put into a holding situation. Often, considerable damage has already been done during the exploration and development stages, and it will remain until the decision to mine is eventually made. For example, an ore deposit near the surface that is to be mined by open pit methods will have been drilled in a close-spaced pattern of vertical holes and the close network of access roads over the property will usually have made a mess of the surface, particularly from the visual standpoint. There are many people who find nothing particularly ugly about a well-engineered and smoothly running open pit mining operation; however, no one would view the drill roads as anything but an eyesore.

Although some properties have lain idle for years or even decades, most economically marginal mining properties will someday become minable. Increased efficiency of mine and mill equipment and increases in metal prices gradually lower the economic "cut-off" grade for ore over the years, and marginal properties eventually are developed.

PRODUCTION

Prior to development of an ore deposit, the exact choice of mining method will have been made. The type of haulageway for one mining method might be totally unsuitable for another method, and it is necessary to plan for production from the very beginning. Underground methods of mining are called stoping by the American metal miner, and are particularly varied.

Underground Mining Methods

The various stoping methods have evolved over the years to cope with particular conditions or to take advantage of certain kinds of labor, equipment, or new techniques as they become available. In selecting the most appropriate stoping methods, the size and shape of the ore body is the most important consideration. Overburden conditions, strength of ore and enclosing wall rock, water, value of ore, and other factors must also be taken into account. Although there are minor variations or modifications of most of the stoping methods, it is usually possible to clearly identify the basic method in use at a given mining operation.

Open Stoping

Small ore bodies are often mined completely out, leaving no pillar of ore in place to support the walls of the stope. In some kinds of rock, it is possible to mine out huge stopes which stand open (fig. 15) for years.

Where some of the ore body is left in place as random pillars to support walls, the material is low-grade wherever possible because it may never be removed from the mine. Sometimes, after open stoping a mine, the pillars are "robbed" just before abandoning that portion of the mine, and the collapse of the stope walls is of no concern to the operation. Sometimes narrow veins can be open stoped, placing an occasional wood stull, or wood beam, from one wall of the stope to the other. This is called stull stoping. The stulls serve to support the vein walls, and as places to anchor wood platforms upon which the miners and equipment stand while drilling ore overhead.

Room and pillar mining (fig. 16) is commonly done in flat or gently dipping bedded ores. Pillars are left in place in a regular pattern while the rooms are mined out. In many room and pillar mines, the pillars are taken out, starting at the farthest point from the mine haulage exit, retreating, and letting the roof come down upon the floor. Room and pillar methods are well adapted to mechanization, and are used in deposits such as coal, potash, phosphate, salt, oil, shale, and bedded uranium ores.

Shrinkage Stoping

Shrinkage stoping (fig. 17) is done by stoping the ore deposit from beneath, allowing broken ore to support the stope walls, but leaving a space above the broken ore just sufficient for the miners to stand on and drill overhead. Broken ore is drawn as necessary to maintain this headroom, and because the volume of rock expands upon breaking, about a third of the broken ore is drawn from beneath as stoping progresses from the bottom of the ore block to the top.

After the stope is completed, all broken ore is removed and the walls are allowed to cave in. The wall rock must be strong enough to support itself during shrinkage stoping, without

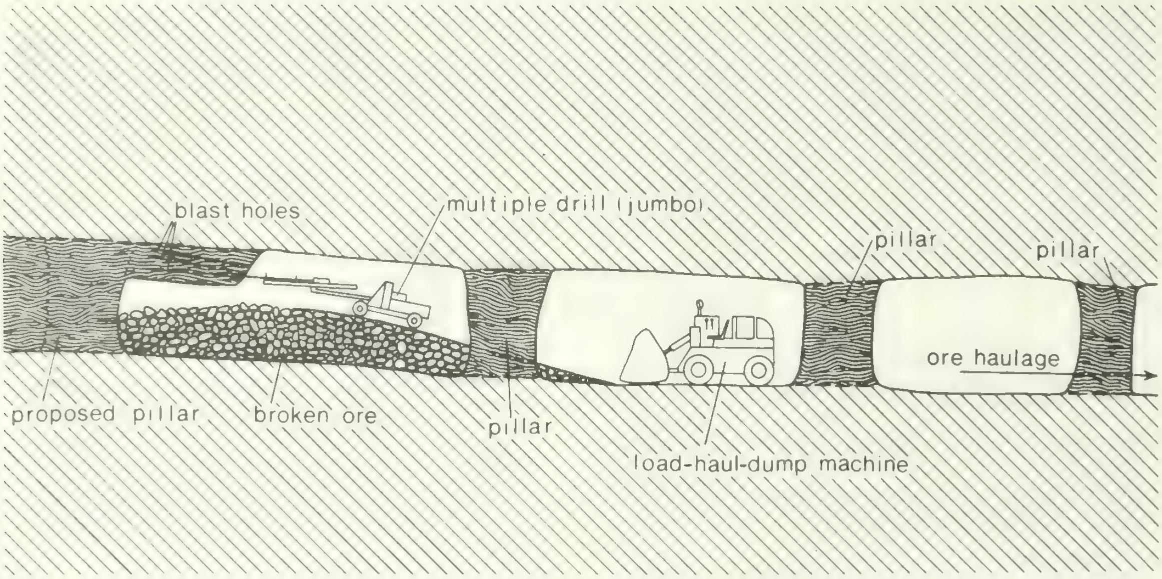


Figure 16.--Room and pillar mining method.

breaking away and becoming mixed with the broken ore. Steeply dipping veins with well-defined, hard walls are most suitable for shrinkage stoping.

Cut and Fill Stoping

The development work for cut and fill stoping is similar to that for shrinkage stoping, except that as each cut of ore is removed, a layer of waste is placed in the stope to support the stope walls and to serve as a platform for miners and their equipment. All ore is taken from the stopes as it is mined, through tightly timbered raises up through the fill, called ore chutes. Broken waste rock is commonly used for fill and usually comes from development headings elsewhere in the mine. This practice makes it possible to dispose of waste rock underground without the expense of hoisting it to the surface for dumping.

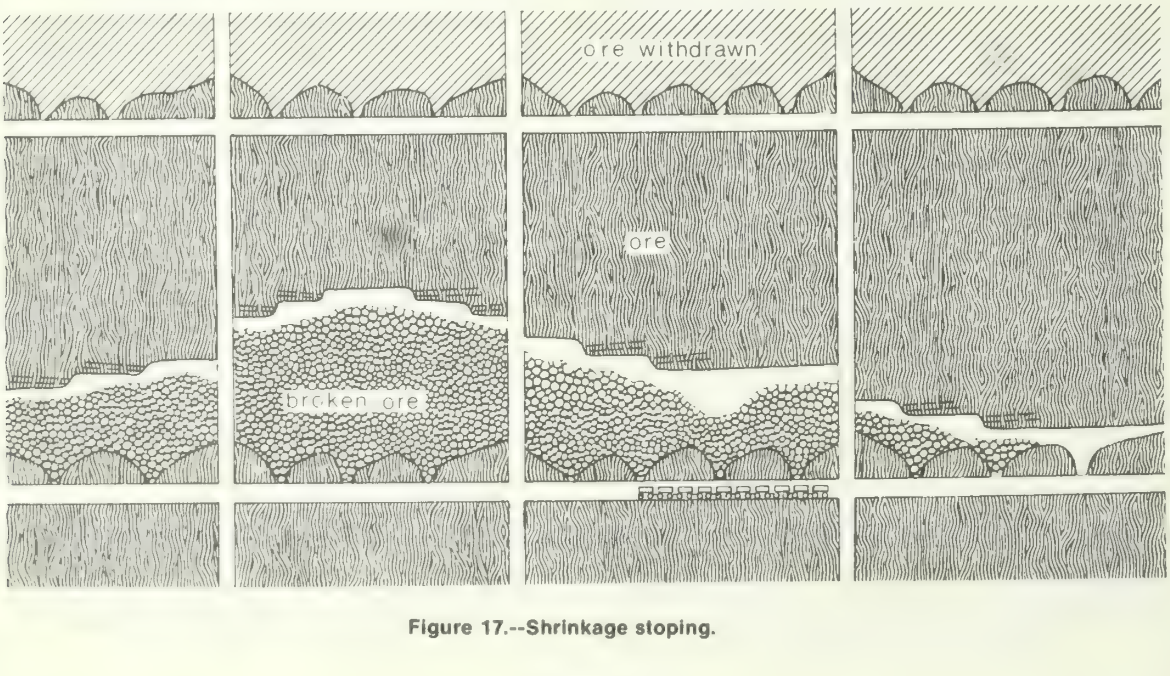


Figure 17.--Shrinkage stoping.

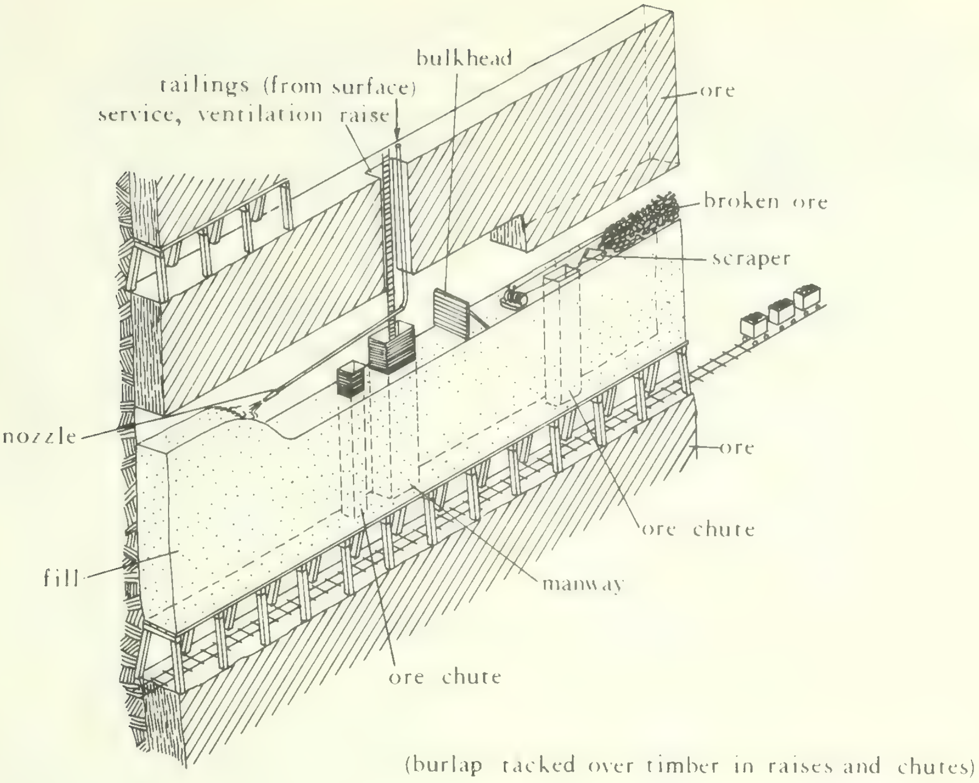


Figure 18.--Hydraulic stope fill.

A variation of the cut and fill stoping methods involves returning carefully sized mill tailings in a slurry to the stopes underground, where the slurry is hosed into place as stope fill under the pressure developed by the head. Water quickly drains from the tailings fill, which becomes compact enough to support the weight of men and equipment as they continue to stope overhead. This method is referred to as hydraulic filling (fig. 18) or sand fill mining and is a convenient way of combining the solutions to the stope fill and mill tailings disposal problem.

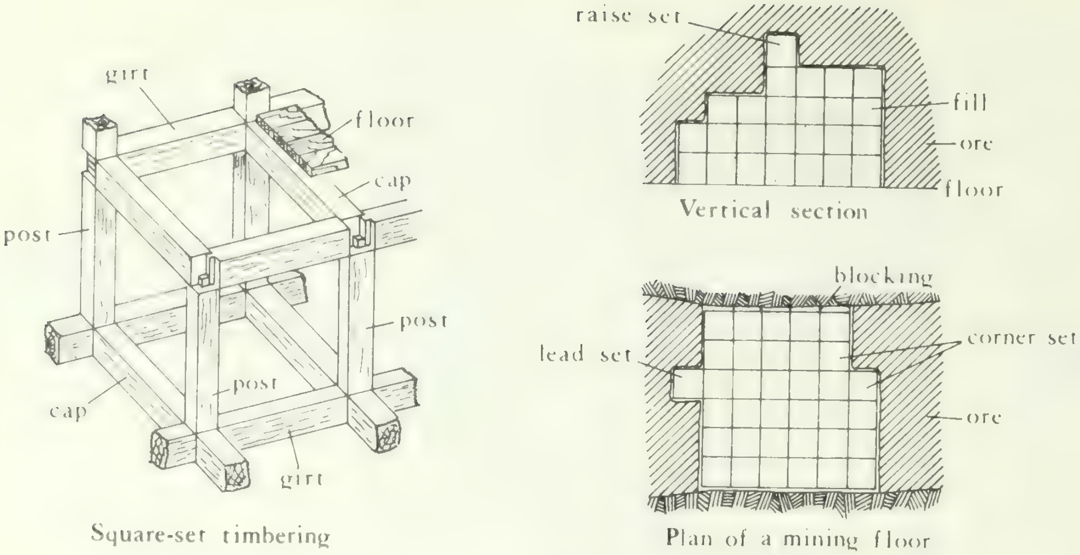
Rill stoping is cut and fill stoping where the slices are inclined to the horizontal, so that ore moves down out of the stope, and waste slides down into the stope from above, without the need for hand shoveling or mechanical scraping. Cut-and-fill stoping methods are used where one or both walls may be weak, so that they would collapse into the stope to mix with broken ore if not carefully supported.

Square-Set Stoping

The square-set method (fig. 19) is used where the ore is weak, and the walls are not strong enough to support themselves. The value of the ore must be relatively high, for square-setting is slow, expensive, and requires highly skilled miners and supervisors. In square-set stoping, one small block of ore is removed and replaced by a "set" or cubic frame of timber which is immediately set into place. The timber sets interlock and are filled with broken waste rock or sand fill, for they are not strong enough to support the stope walls. The waste rock or sand fill is usually added after one tier of sets, or stope cut, is made.

Block Caving

The block caving method (fig. 20) is used in mining large ore bodies that have a barren or low-grade capping too thick to strip away from the surface. In development, evenly spaced



Square-set timbering

Vertical section

Plan of a mining floor

Figure 19.--Square-set stoping.

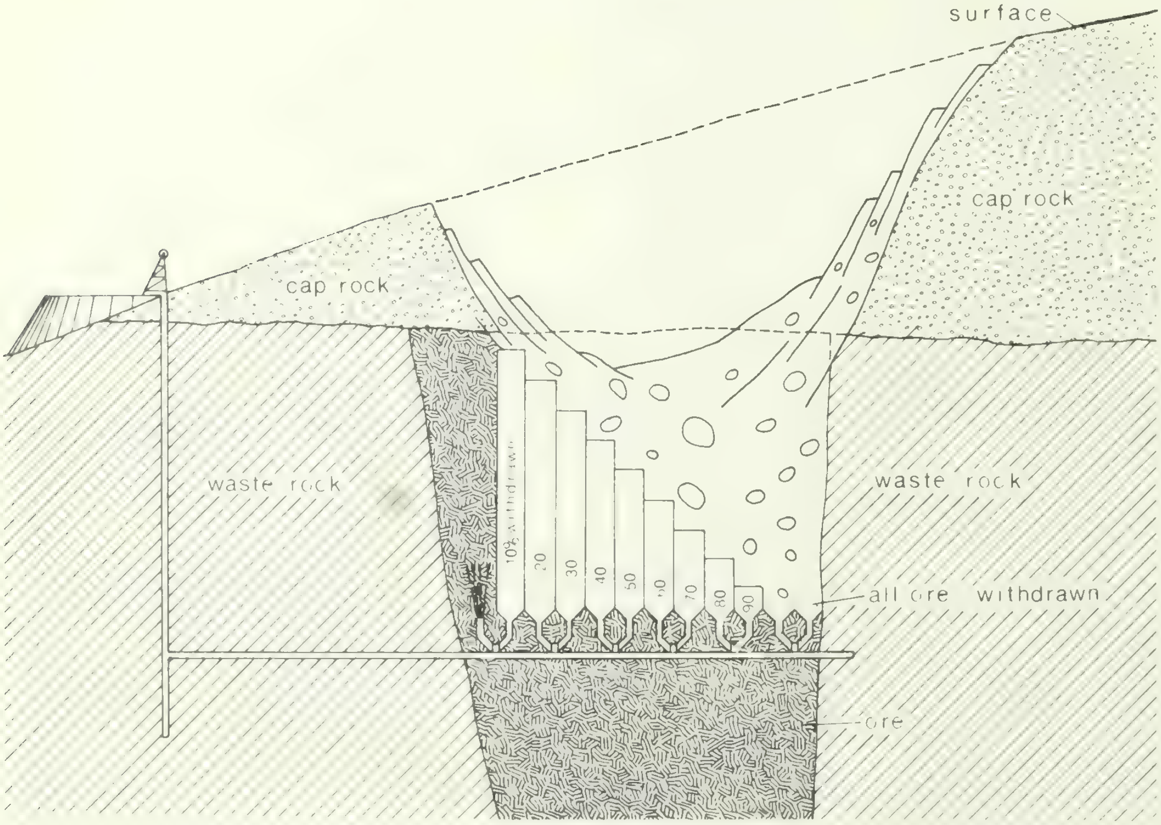


Figure 20.--Block caving underground.

crosscuts are made below the bottom of the ore block to be caved, from which raises are driven up to the ore. The entire ore block is undercut so that it will begin caving into the raises. The weight of the capping and ore provides the force to crush and move the ore downward, where it is drawn from the raises beneath, trammed to the shaft or decline, and hoisted to the surface.

As broken ore is removed, the capping will gradually descend until broken fragments of it coming from the raises indicate that all of the ore has been withdrawn. The surface over the worked-out mine is a gigantic collapse feature, not as deep as the height of ore withdrawn, because of the "swell factor" of the broken capping, but considerably larger in diameter than the area actually caved underground.

Surface Mining Methods

Because of the rapid development of many types of large and efficient earthmoving machinery and auxiliary equipment, surface mining methods have made it possible to mine many ore deposits that would be uneconomic to develop underground. Although there is great variation in detail, only a few basic methods are employed, and the terminology is much more simple than in underground mining.

Placer Mining

Placer deposits are concentrations of heavy minerals, usually within loose alluvium that can easily be excavated and washed. Placer minerals such as gold, tin, and tungsten minerals, are of relatively high value, but the value of the placer gravel itself may be very low, often less than a dollar per cubic yard. For deposits of such low grade to be worked they must be near water, on or near the surface of the ground, and should be only loosely consolidated so that drilling and blasting are not necessary. The bulk of placer mining falls into three groups--panning and sluicing hydraulicking, and dredging.

Panning and sluicing.--The traditional gold miner's pan is an efficient device for washing and separating placer minerals. However, the method is slow, and even in the hands of a skilled operator only small volumes of material can be processed. Most surface deposits rich enough to be mined and concentrated by panning were worked over long ago, in many cases by Chinese workers left idle after the construction of the transcontinental railroad. With today's high wages and employment opportunities, the deposits remaining are far too low grade to be worked on a sustained economic basis. The gold pan is now used mainly as a tool in prospecting and exploration of low-grade placer deposits being considered for bulk mining methods such as dredging.

In recent years, gold panning has become a popular outdoor recreation. There is excitement and appeal in panning an occasional nugget or a few small specks of gold. The remote chance of discovering a rich pocket somehow missed by the oldtimers provides a stong incentive. In general, far more money is made selling manuals, maps, equipment, and gas and oil to these hobbyists than is made from the gold itself. There are shops along the foothills of the Sierra in California where small quantities of placer gold are sold at great mark-up over metal market quotations, so that the unlucky weekend gold panner need not return home emptyhanded.

In sluicing, the placer gravel is shoveled into the head of an elongated sluice box which is inclined and has various configurations of bars and traps across the bottom called riffles. Water is directed through the sluice box, and the heavy placer minerals are trapped in the riffles; the fine material is washed over them and out as a relatively barren tailing. Few deposits are left unmined in the western United States, where sluicing might be economical at present gold prices.

In both panning and sluicing operations, it is sometimes possible to collect very fine particles of gold by amalgamation, when mercury is either placed in the bottom of the riffles or smeared on copper plating. The fine gold amalgamates with the mercury and is collected by retorting in small devices which drive off the mercury as vapor, retaining the gold.

Hydraulic mining.--In hydraulic mining, or "hydraulicking," a stream of water under great pressure is directed against the base of the placer gravel bank using pipes and large nozzles called giants. The water caves the bank, disintegrates the gravel, and washes the broken material to and through sluice boxes situated in convenient positions downslope. Hydraulic mining totally disturbs large surface areas, puts much loose debris into the drain age system, and involves large surface water runoff that may cause substantial damage downstream. Many of the western States passed laws years ago to closely control "hydraulicking," and few substantial deposits of placer gravel remain that could be mined economically within the restraints of this legislation.

Dredging.--Large alluvial deposits are mined by floating washing plants capable of excavating the gravel, processing it in the washing plant, and stacking the tailings away from the dredge pond. Two kinds of equipment--bucket line and dragline--have been used. The bucket line dredges are larger and more efficient, consisting of a continuous line of buckets that scoop the material from the gravel bank at the edge of the dredge pond, raising it to the top of the washing plant mounted in the hull. Dragline dredges are smaller and less efficient, and employ a single bucket that digs the gravel and is swung over the feeder hopper of a floating washing plant similar to the layout in a bucket line dredge, although usually smaller.

Dredging temporarily involves total disturbance of the ground surface, although with careful planning and engineering of the operation it is possible to plan for restoration of the surface, and perhaps even to improve some aspects of the floodplain or nearby river channel. It is not possible to restore the land to the precise original contour, for the swell factor of the gravel increases volume 20 percent or more. In many areas in the West, particularly near major construction projects or cities, clean gravel placer tailings are valuable for manufacture of aggregate, or crusher run, in fills of various kinds, and can be considered a resource in their own right. In a few areas, people traveling through areas of old placer tailings, expecting the area to be some sort of wasteland, are pleased to find a great variety of fishing and water sport recreation available, and thriving wildlife in the habitat that has been created.

Because large placer deposits can be thoroughly explored before floating the dredge, such operations lend themselves to thorough planning, and it is possible to do a considerable amount of reclamation at only slight increase in overall operating costs.

Glory Holing

Almost every opening at the surface is referred to by local writers and mining buffs as "glory holing" (fig. 21). Actually this kind of operation is uncommon, as it involves a mine opening at the surface, from which ore is removed by gravity through raises connected to

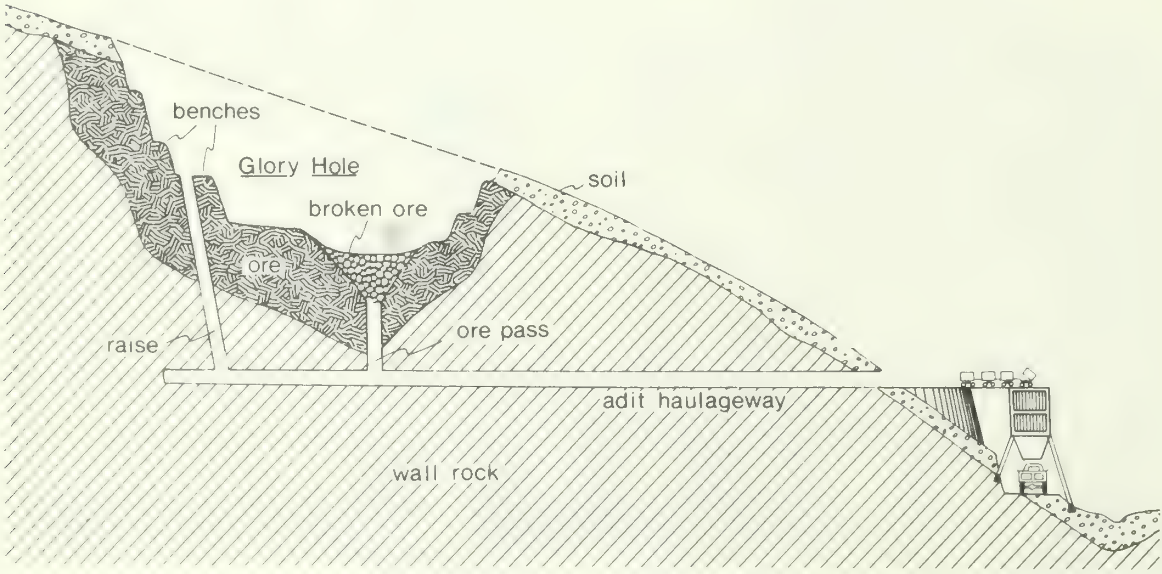


Figure 21.--The glory hole mining method.

adit haulageways beneath, and by tramming the ore to the surface on the haulage level.

The glory hole method is best suited to mining on a hillside, and irregular deposits can be cleanly mined without dilution by waste wall rock. Narrow veins have been mined by glory hole; in these cases the "hole" becomes narrow and long. The benches are mined away as work descends to the bottom of the deposit or to the haulageway, so that spectacular steep sidewalls may result if the walls do not slough in. Mining can be quite selective, and little waste rock is thrown on the surface dumps. The principal environmental objection to the method is difficulty in reclamation of the surface of the mine area.

Open Pit Mining

Although the basic concept of an open pit (fig. 22) is quite simple, the planning required to develop a large deposit for surface mining is a very complex and costly undertaking. In one mine, it may be desirable to plan for blending variations in the ore so as to maintain, as nearly as possible, a uniform feed to the mill. At another operation it may be desirable to completely separate two kinds of ore, as for example, a low-grade deposit where one kind of "oxide" ore must be treated by acid leach, but a second kind of "sulphide" ore must be treated by different methods.

The grade and tonnage of material available will determine how much waste rock can be stripped, and there is often an ultimate limit to the pit that is determined more by the economics of removing overburden than a sudden change in the ore deposit from mineral to nonmineral bearing material. The ultimate pit limit and the slope of the pit walls are therefore determined as much by economics and engineering as by geological structure. Material that is relatively high grade may be left unmined in some awkward spot extending back too deeply beneath waste.

The typical large open pit mining operation that has been in production for 10 years and more is operating under conditions that could not possibly have been foreseen by the original planners of the mine. Metal prices, machinery, and milling methods are constantly changing so that the larger operations must be periodically reevaluated, and several have been completely redeveloped from time to time as entirely different kinds of mining and milling operations.

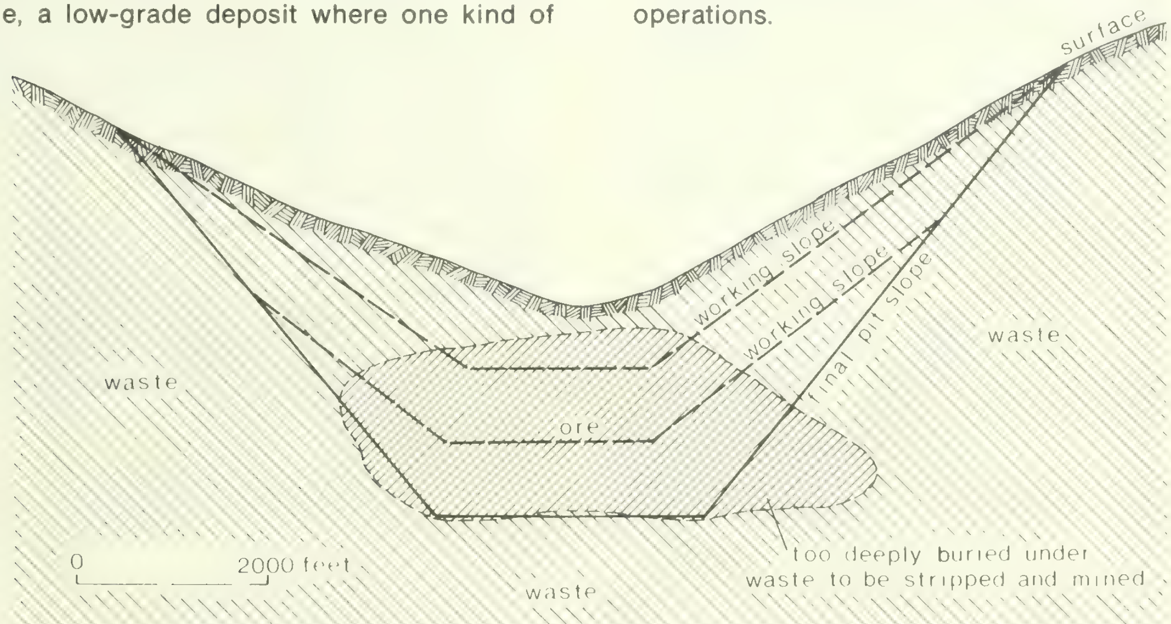


Figure 22.--Open pit mining.

Sometimes the preliminary stripping of the waste overburden is contracted to firms specializing in earthmoving. Mining is usually done by track-mounted electric shovels in the large operations, and by rubber-tired diesel front-end loaders in the smaller operations. Scrapers are sometimes used in special situations. Large bucket-wheel excavators of the kind used in European coal mines have not been applied to metal mining, because this equipment is best adapted to softer bedded, relatively flat-lying strata.

Haulage is usually by truck, although railroads, inclined rails, and conveyor belts have been used. The conveyance unloads directly into a primary crusher and crushed material is stored in coarse ore bins prior to shipment to the mill.

Bench level intervals are to a large measure determined by the type of shovel or loader used, and these are selected on the basis of the character of the ore and the manner in which it breaks upon blasting and supports itself on the working face. Blastholes are usually drilled vertically by self-propelled, track-mounted pneumatic or rotary drills. Bulk explosives are loaded in the holes and large volumes of ore are broken in a single blast. Sometimes the drill holes are routinely sampled and assayed to help plan the position of the shovels in advance of mining. Blasthole assay control is especially desirable when exploration data are incomplete or lacking as in the case in the older pits which have long been mined past the limits of "ore" used in original planning.

Leaching Methods

Solution mining techniques are used for extracting soluble ores such as potash and salt in situations where conventional mining methods would not be economic. Total solution of all the mineral is not always accomplished. Sulfur is mined by the Frasch process, using steam to melt the sulfur and bring it to the surface through bore holes. The future of solution mining appears promising, for there is constant improvement in equipment, solvent, and in technology of breaking rock in place and controlling the movements of fluids through it. In mining salt, potash, and sulfur, the overburden and surface over it subside. Subsidence it desirable, because it increases the solution of mineral, and destroys voids, reducing the amount of solution required and the time needed for it to act.

In applying methods of solution mining to traditional ores such as the base and precious metals, subsidence will not be as important as surface disturbance, for the metal taken into solutions is only a minute portion of the total rock matrix. It has been suggested that some zones of low-grade mineralization might be leached in place, and there is particular interest in copper and gold ores, which have long been leached using "vat" processes and uranium, which is easily taken into solution in a number of solvents.

Biologic activity is known to hasten the conversion of metal in many ores to a more soluble form. Several naturally occurring bacteria have been found to oxidize such insoluble minerals as copper sulphides, increasing solubility a thousandfold over the sterile condition.

A great deal of research is being done to determine the conditions most favorable for good solution of metal, and the method can be expected to contribute significantly in future mining operations, if not become an important mining method in its own right. Operators are particularly watching developments of new organic solvents that are environmentally acceptable, are specific for the element desired, and do not react with or become consumed by wall rock.

The methods most commonly used for distribution of leach solution are flooding ponds over the leach dump, spray, trickle, and solution injection. The pregnant solutions are collected beneath the leach zone and are pumped to precipitation plants nearby or to the precipitation section of the main ore treatment plant where this is feasible.

In-Place Leaching.--Because the natural porosity of most rocks is too low for rapid, pervasive penetration of leach solutions, it is necessary to fracture the rocks artificially. Conventional explosives have been used, and one low-grade copper deposit in Arizona is repeatedly suggested as a likely place to research underground use of a nuclear device, where breakage, heat, and pressure would combine to make the copper sulphide minerals much more soluble than in ambient conditions.

On a more limited scale, in-place leaching has been applied to fill in old mine stopes, caved areas over block caving operations underground, and in peripheral portions of conventional open pits where the grade is too low to permit mining the material.

This method is not well enough understood, nor has enough experience been gained to apply it to a virgin, high-grade ore deposit with assurance of control and predictable recovery of values being leached. The method holds great promise, because capital costs are low and there are fewer environmental problems compared to the movement of vast tonnages of rock in conventional mining.

Mining Dumps.--Low-grade copper mines usually employ some form of leaching for recovery of small amounts of copper contained in overburden and waste. Open pit gold mine operators have begun to follow this practice, particularly where the pregnant liquor can be pumped to the precipitation section of an existing metallurgical plant. Usually no special consideration is given to the preparation of the mine dump for leaching, and in fact the decision to leach often comes after the dump was laid down. Where it is possible to plan ahead for leaching, the following operations are standard practice:

1. All vegetation is removed over the dump area.
2. The surface of the dump area is compacted and overlain by impervious material such as clay.
3. Fine material should be separated.
4. A long, narrow dump may be desired to promote natural aeration.
5. The surface of the dump is ripped, or otherwise uncompacted.
6. The dump material may be moistened as it is laid down, inducing oxidation while the material is still in direct contact with atmospheric air.
7. The dump may be leached in a series of "lifts," which has been found to be more efficient than attempting to leach the entire waste dump in a single operation.

Heap Leaching.--Heap leaching is applied to ores where the grade is too low to pay for haulage, conventional concentration, or leaching in a vat operation. Complex ores that cannot be treated economically by conventional processes may be mined and heap leached. The techniques are no different than for leaching mine dumps, except that the operation is totally planned, and the precipitation plant is often specifically designed for the purpose, rather than being a section of the plant at a conventional metallurgical operation. Heap leaching has been applied mainly to low-grade copper and uranium mineralization, although there is presently much interest in the method for precious metals.

Ore Dressing

At most modern mining operations, whether surface or underground, the ores are not rich enough to ship long distances to smelters, and they are subjected to milling, mineral dressing, or beneficiation. All of these terms are sometimes referred to as ore dressing. Ore dressing is the mechanical separation of the grains of ore minerals from the worthless gangue. The resulting concentrate contains most of the ore minerals, and the waste is called tailings.

Crushing and Concentration

Usually two stages of crushing are used in ore dressing because it is more efficient than crushing to a relatively small size in a single-stage operation. First stage, or primary, crushers are usually jaw crushers in small operations and gyratory types in larger operations. Primary crushers and the coarse ore bins may be located at the mine, where the mine and mill operation are separated. Secondary crushers and the fine ore bins are usually at the mill, along with blending or custom facilities where more than one kind of ore is mined or received. The fine ore is ground in ball or rod mills to a size small enough to liberate the ore minerals, then classified in various kinds of machines to insure that the feed to the mill is uniform.

The various ore dressing methods are based on physical characteristics such as density, wettability, chemical reactivity toward certain reagents, and magnetic characteristics.

Flotation.--Flotation is the most widely used method of beneficiating complex and low-grade sulfide ores in the western United States. The word "concentrator" is virtually synonymous with froth flotation plant. The crushed, ground, and classified ore is pulped with water, and special reagents are used to make one or more of the ore minerals water repellent and responsive to attachment with air bubbles. As the desired minerals are buoyed to the surface by the attached air bubbles, they are removed by mechanical paddles as concentrate, leaving the other minerals behind. Often several stages of flotation with selective reagents are employed to obtain the desired concentration.

Pneumatic, or air, flotation cells are long, open troughs through which the pulp flows, and gas bubbles are introduced from the bottom to accomplish agitation and frothing. Mechanical cells are boxlike and are agitated by a rotating impeller through which air bubbles are introduced.

Gravity.--Gravity methods of concentration are based on the simple fact that the ore minerals are heavier than the gangue. Gravity may be the sole method of concentration, or the equipment may be a part of the mill "flow" scheme, where waste material is separated in a series of steps. The jig is a boxlike apparatus containing a submerged screen that supports a bed of ground ore. The ore is stratified by the action of two pulses of water, one upward, downward, alternating in rapid succession. During this pulsation, particles of different density arrange themselves according to size and specific gravity, the tailing forming the top layer, a fine concentrate passing through the screen, and a coarse concentrate forming in a layer on the screen.

Shaking tables are inclined, elongated decks with cleats nailed to the surface. The table is vibrated lengthwise with a slow motion in one direction and a rapid return. A thin layer of water flows down and over the deck, and slurry feed is introduced at the upper corner. Small, heavy particles ride high on the table, parallel to the cleats, to the end where they are collected. Light material washes over the cleats, down to the lower side where it spills over into a trough and is directed toward the tailings disposal area.

Where heavy, insoluble minerals are involved, a liquid of specific gravity intermediate between ore and waste can be used to make the separation in the process called sink-float. The ore need be broken only fine enough to separate ore minerals from waste, and in some deposits this means simple screening of the material as it comes from the mine, breaking oversize to 6 inches or more. Low-grade barite ores have been economically upgraded using the sink-float process, and the method has found application in upgrading coal.

Magnetic Separation.--Approximately 20 ores are magnetic enough to be separated by the magnetic process. The separation can be either wet or dry. In one wet process, magnetic drum separators are used to lift the magnetic particles from a stream of ore pulped with water. In a typical dry process, the magnetic particles are lifted from the moving stream of ore by a fast moving magnetic cross belt.

Extractive Metallurgy

Extractive metallurgy involves the recovery of metals and metal compounds from ores and mineral concentrates. Pyrometallurgy, hydrometallurgy, and electrometallurgy are the principal methods involved. As these names imply, heat, aqueous solutions, and electric current are used to produce metals and metallic compounds of sufficient purity for the market.

Pyrometallurgy.--Electrical energy is used or fuels are burned to apply sufficient heat in refractory-lined furnaces to melt the charge of ore or mineral concentrate in the pyrometallurgical process. Some minerals are volatilized at elevated temperatures and can be recovered by distillation from kilns, furnaces, and retorts. Other metals can be separated by liquation, using differences in melting point.

Smelting is by far the most important of the pyrometallurgical processes. The ore and waste minerals are heated, altered, fluxed, or reduced to form a low-density slag and one or more liquid metals. Only high-grade ores or concentrates can be smelted because of the high cost. It is usually necessary to further refine the metal to a product of acceptable purity.

All pyrometallurgical operations produce large volumes of gas containing a wide variety of vaporized metals, dust, and fumes. Many smelters are large centralized installations that have gradually evolved over the years at some major seaport, rail point, or other shipping center. Only in a rare situation would a smelter be planned near a single mining operation in a region with relatively poor transportation facilities.

Hydrometallurgy.--Hydrometallurgical processes selectively dissolve metals from ores and concentrates, resulting in recovery of relatively pure metal. Various acids, such as sulfuric acid, and alkaline solvents, such as the hydroxides and carbonates of sodium or ammonium, are popular in leaching ores. Sodium and calcium cyanide solutions are widely used in extracting gold and silver from precious metal ores.

The usual technique is to agitate finely ground ore or concentrate in open vessels at atmospheric pressure. Vat leaching percolates crushed ore bedded in large, stationary, rectangular, or circular containers. There is presently much interest in these processes, because many ores that were formerly smelted may be treated by hydrometallurgy with far less air pollution and consumption of energy.

Electrometallurgy.--Two kinds of electrometallurgical processes are in general use today. In one, the electric current is used as a source of heat; in the other, the current is used in electrolytic depositon on cathodes. Electrical heating is substituted for fuel heating where precise control of temperature is required, or the atmosphere of the furnace or purity of the metal is of concern.

Electrolytic processes include two general methods, one using an aqueous electrolyte, the other a fused salt electrolyte maintained at high temperature. The aqueous electrolyte method is widely used to purify metal produced by pyrometallurgical methods.

Wastes

Some high-grade ore deposits are so massive and so easily distinguished from wall rock that they can be removed by highly selective mining methods underground. A moderate amount of waste rock produced during development of haulageways through barren wall rock can often be disposed of as stope fill with the result that there are no large waste dumps at the surface. More often, a considerable amount of barren or low-grade material is taken from the mine during exploration and development, and disposal of broken waste rock on the surface is a major problem.

Mine Wastes

In mountainous terrain, particularly where development is by adit and where access is difficult, waste dumps are located in or near the stream bottoms. Normally, waste is dumped just beneath the level of the adit portal or shaft collar.

Where a reservoir may be desired as a source of water for mine, mill, and townsite, it may be possible to locate the mine waste dump so as to impound water. Many such reservoirs have become important recreational assets for employees and the public.

There is no general fixed ratio for the amount of waste produced compared to ore, but in most cases it is less than 1:1 waste:ore in underground mining operations. At certain points in the development of bulk mining operations, such as block caving, for brief periods virtually all of the material taken from the mine will be waste rock. Shafts for ore haulage systems may deliberately be laid out well away from the ore body in waste rock to insure that these facilities will not be damaged or destroyed by mining.

Open pit operations, such as phosphate and copper, produce far more waste rock than underground methods, and disposal of this material is a major aspect of the operation. It is common for the ratio of waste to ore to exceed 1:1, and in some cases 10 tons or more of waste are removed for each ton of ore taken from the pit.

In the large view, some planners see major open pit mines as a solution to the surface disturbance problem. They are efficient and highly productive of metal, concentrating disruption in one local area rather than having the same production come from tens or hundreds of smaller operations scattered through the region. For example, in Nevada, one small cluster of open pit copper mines, embracing an area of several square miles, has produced more copper and molybdenum than all of the other mines in the State combined, by a very wide margin.

As in other kinds of surface reclamation, it is usually much more economic to plan the best waste disposal before the material is placed. Satisfactory solutions can often be worked out beforehand at an acceptable increase in operating cost, particularly where the solution can be coordinated with other phases of the operation, such as providing a superior yard facility for the machine shops or better layout of a mine dump leaching operation.

There is a certain amount of noise pollution in drilling, blasting, movement of large equipment, and the operation of air compressors, powerplants, crushers, and mills. This noise usually affects only the people in the immediate area of the mine and mill, who are employees of the operation. Most mine operators are attempting to reduce noise wherever possible, in line with recent industrial safety studies, which show that worker fatigue can result from noisy environments.

The water draining from newly opened or abandoned mines can have a major impact upon the environment downstream. Solid particulate matter may be introduced in sizes ranging from fine silt to sand, and consisting of relatively inert material, although chemical reactions may convert some or all of it to more soluble chemical compounds. Radioactive material may be involved in some cases, and organics may be introduced into surface waters. Mine waters are often "acid" because of the common association of the iron sulphide pyrite with most metal ores and many solid fuels. Pyrite, as well as a number of other ore and gangue minerals, rapidly decomposes when broken and in contact with moisture and air, producing sulphuric acid. This chemical reaction proceeds spontaneously, and the acid mine water then has the ability to take other pollutants into solution.

Mines where broken or ground pyritic material has been used as stope fill are particularly likely to produce acid water; it is possible to minimize this to some extent by shutting off this portion of the mine, or otherwise keeping the supply of oxygen and moisture from these areas. Alternatively, a mine can be partially or entirely flooded with water to eliminate oxygen.

When it becomes necessary to reopen old mines, they are often found to be partially flooded with acid water containing much dissolved material. It may be possible to gradually release such water into surface drainage during the runoff season. Sudden release during low water would cause major environmental damage. It is sometimes possible to treat mine water by various processes before releasing it, as for example neutralization of acid by using lime or caustic soda. Mine water may be used directly in the mill boilers, where it may be recycled to further reduce contamination of surface water.

Some mine water is of sufficiently good quality to become an important local source and environmental asset.

Mill Wastes

Because most mill wastes are finely ground and are moved to disposal areas in a water slurry, particular problems are encountered with the environment. In many milling operations the ore constitutes only a small portion of the material recovered as concentrate. For example, only 2 or 3 percent of the weight of ore in a low-grade copper mine ends up as concentrate. The 97 to 98 percent waste must be disposed of as mill tailings, which are directed through ditches, launders, and pipe systems to pond disposal areas downhill from the mill. In some cases, mill tailings can be classified and returned underground to be nozzled under pressure as stope fill.

Mill tailing ponds are usually impounded behind embankments built from the tailing material itself. Sometimes it is necessary to install drainage systems beneath the dam and pond area to facilitate drainage where the natural ground is not sufficiently porous. The site should be selected so that surface water cannot erode the toe of the embankment. It is usually necessary to construct a catchment pond downstream from the embankment to collect seepage water and tailings eroded from the face of the embankment. Decant systems take off the water after solids have separated, and the floor of the pond gradually rises as disposal continues. A major threat to the tailings pond is overflow of the embankment due to flooding in the drainage system above the tailings. Abandoned, poorly designed tailings ponds are quite troublesome in this regard, particularly where no attempt was made to stabilize the surface, or to divert surface water away from the area.

When the surface of an unstabilized tailings pond is allowed to dry, major pollution of the nearby area can occur when fine particles are picked up by the wind. Proper location, design, and operation of the disposal system minimizes some of the difficulties. Again, old abandoned tailings are often a major problem.

Dissolved metals and salts, in highly toxic solutions, are sometimes found leaching from mill tailings. Modern practice is to remove this material where it is at all feasible to do so.

Miscellaneous Junk

In many of the old mining camps of the West, every trace of former mining activity has been removed by scavengers to the point that the exact position of some small districts of historical record can no longer be found with certainty. In some areas of more recent activity, for example the gold mines of the 1930's and tungsten mines of the 1950's, the mine buildings and equipment are less romantic, gradually having fallen into a state of vandalized disrepair that in every way qualifies them as the prime local eyesore. Eventually, all of the iron will be taken for scrap, the tanks appropriated by local ranchers and farmers, and the wood and galvanized sheeting hauled away. In the meantime, there is often little that can be done to quickly clean up these areas, unless some local regulation permits them to be classified as esthetic nuisances or safety hazards.

If a considerable amount of junk has been left in a district or group of districts, it may be possible to arrange for outside scrap collectors to make contact with the owners for a bid on salvage. Caution should be exercised, however, for these old facilities sometimes are classified as genuine antiquities at about 50 years of age, and public sentiment may be very much divided as to the merit of removal.

In presently operating mines, or newly planned operations, it is possible to insure removal of the surface plant and equipment. There are problems, however, with the law insofar as the rights to structures on lands optioned or leased from private individuals that may for one reason or another revert to original ownership.

Roads

In most cases, where public funds are used for road construction and maintenance, the public may have some use of the roads. This may abruptly terminate at the mine property boundary, and a gatekeeper may allow entry only to company employees or people having legitimate business on the property. There are a number of reasons why mining companies do not permit people to enter the property at will. An unsuspecting tourist could easily drive off an open pit bench, fall into a tank full of solution, or become involved in any one of a hundred other industrial hazard situations. Exposure to public liability alone is enough to make most companies enclose the mine and mill area in chain link fence.

Many companies recognize the damage to their public image when the typical curious tourist may suddenly be confronted with a curt rebuff at the end of a well-traveled and maintained road, and thought is usually given to minimizing the effect. Most open pit operators arrange guided tours or self-guided vantage points where the visitor can gain a clear perception of the mine operation, yet stay at a distance where he will not be in the way or exposed to any risk. Mine tours and viewpoints engender a great amount of good will for the mining industry, and go a long way toward eliminating a potential source of friction between mine operator and the public.

Many mine operators recognize that facilities such as reservoirs, or the drainage system behind them, that provide water for mine, mill, and townsite have a considerable recreational potential for employees. Because local fish and game authorities will not usually stock or manage game on private lands from which the public has been excluded, and because of probable adverse public opinion if the areas are restricted to employee use, such recreational areas are often opened to the public, with the normal restrictions of a private landowner. More than the usual number of signs cautioning potentially hazardous situations are posted, because of the private landowner's exposure to possible liability. Companies have been known to subsidize or entirely finance boat landings, beaches, parks, camping facilities, and ski lifts and lodges, and have been involved in game management programs, such as stocking of fish and reintroduction of game animals, where such projects would not be economically sound for a private individual.

The public is allowed use of mine access roads to recreational areas. There are sometimes unusual traffic controls, rights-of-way, and traffic movement patterns. One-way traffic may be necessary at certain times on narrow roads where large off-highway units are used. Water trucks may dissipate dust almost continuously to improve driving safety and to reduce wear on truck bearings and engines. On unsurfaced haulage roads where large trucks are used, the traffic flow is often directed so that loaded trucks are against the hill rather than out on the bank, where the weight of the load may break the edge of the road down, and where the driver might experience difficulty if he were to suddenly lose control. This results in a considerable amount of travel on the left side of open pit haul roads.

When a road has been constructed by the Forest Service for Forest purposes, the miner who desires to use it may be required to share the cost of maintenance, based perhaps upon a ton per mile fee for the miner's proportional use of the road. The miner may be required to maintain or help to maintain such a road in the condition it was originally designed for.

RECLAMATION

There is a widespread public feeling that the mining industry has defaced vast areas; this belief probably in part originates because roads and other transportation facilities are well-developed in established mining areas. The area affected by mining is about a sixth that devoted to highways, and is approximately equal to that used for airports in this country. In terms of benefit to the Nation, mining is essential and in all fairness modern, well-planned and operated mines are not the despoilers many believe them to be.

Over the years, the increased size and efficiency of powered excavation equipment and improved drilling and blasting techniques have resulted in very low cost mining operations. As the individual and total number of these bulk mining operations have grown, so has public interest in reclamation of the surface disturbance resulting from them. Many States now require land reclamation as an integral part of mine planning. A large percentage of mined land is now being reclaimed, or at least partially reclaimed to an acceptable condition.

Extensive research is being conducted by mining companies, several Government agencies, including the Forest Service through its SEAM program, and university scientists on the many technical facets of reclamation. Results are being shown at demonstration areas, and are being rapidly incorpoated into mine planning and continuing operations.

This brief chapter makes no attempt to discuss the many technical facets of reclamation. Rather, it briefly presents several general concepts.

Satisfactory reclamation should emphasize three major objectives:

1. The productivity of the reclaimed land should at least equal that of the premine sur-

face. This does not necessarily mean that the site must be restored to an approximation of its original condition, or that surface uses after mining will be the same as those existing prior to mining. For example, an area used for marginal grazing prior to mining may be changed to a useful and attractive recreational complex, or perhaps in another case to a housing area.

2. Satisfactory reclamation should leave the mined area in a condition that will not contribute to environmental degradation either in the form of air- or water-borne materials, or from chemical pollution.

3. The reclaimed area should be esthetically acceptable and it should be safe for the uses intended.

Reclamation goals must not only be technically feasible, they must be economically attainable. In some cases restoration to the original contour is not practical. For example, in a major open pit copper operation, 500 million tons of ore are mined and sent to the mill, and a billion tons or more of overburden will be placed on waste dumps. Milling will result in almost 500 million tons of tailings, and 10 to 15 million tons of concentrate that will be shipped to the smelter, and from which 5 million tons of copper metal will be recovered. The excavation of a billion and a half tons will leave a hole nearly a cubic mile in size. Using presently available mining methods, particularly at mines already partially developed, it is not possible to economically replace the mine and mill wastes and to restore the surface to anything like the original contour. Planning must take the reality of the situation into account and aim toward possible ultimate benefit to be derived from a surface configuration much different than prior to mining.

There are no cut and dried standard formulas for accomplishing reclamation. Almost every case differs and is influenced not only by natural variables such as climate and the material to be worked with, but by social variables such as the laws of the particular State where the operation is located, the ownership of the land, and the goals the public may wish to see pursued through reclamation. In addition, the operator's requirements as to methods of mining and timing will affect the final decision concerning specific prescriptions for reclamation.

Mining companies now generally have expertise available for planning reclamation. Land managers can be of assistance by participating in the planning process and by contributing technical knowledge where possible and where needed. Assistance often can be given on specific information such as plant and wildlife species, seeding methods, labor sources, and plant material sources. The final decisions on reclamation will most often be the result of the combined contributions from many sources, both public and private. Reclamation ideally is just another end result of thorough mine planning.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

- Billings, Montana
- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with the University of Nevada)

U.S. Department of Agriculture, Forest Service
1977. Anatomy of a mine: from prospect to production. USDA For. Serv. Gen. Tech. Rep. INT-35, 69 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Reviews mining laws and regulations and their application to mining in western States. Describes prospecting, exploration, mine development and operation, and reclamation factors.

KEYWORDS: mining law, mineral exploration, mine development, mine operation, mining area reclamation.

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1977. Anatomy of a mine: from prospect to production. USDA For. Serv. Gen. Tech. Rep. INT-35, 69 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Reviews mining laws and regulations and their application to mining in western States. Describes prospecting, exploration, mine development and operation, and reclamation factors.

KEYWORDS: mining law, mineral exploration, mine development, mine operation, mining area reclamation.

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GUIDELINES FOR REDUCING LOSSES OF LODGEPOLE PINE TO THE MOUNTAIN PINE BEETLE IN UNMANAGED STANDS IN THE ROCKY MOUNTAINS

Gene D. Amman, Mark D. McGregor,
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USDA Forest Service General Technical Report INT-36
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

Cover Photo.--Mountain pine beetles have killed many trees in this lodgepole pine stand on the Targhee National Forest in southeast Idaho. Red trees that have retained most of their needles were killed in July or August of the preceding year. Gray trees and those with few red needles were killed during previous years.

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GUIDELINES FOR REDUCING LOSSES OF LODGEPOLE PINE TO THE MOUNTAIN PINE BEETLE IN UNMANAGED STANDS IN THE ROCKY MOUNTAINS

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INTRODUCTION

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, presents the most serious threat to growing lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, for sawtimber and maintaining it for other purposes, including esthetics. Populations of the beetle periodically increase and kill most of the trees of large diameter in a forest before subsiding. The frequency of epidemics appears to be directly related to site quality, with stands on better sites growing into a susceptible state more rapidly than those on poor sites. Specifically, frequency and intensity of beetle epidemics are related to age, diameter distribution, phloem thickness distribution, and elevation and latitude of the stand. Although these are by no means all the factors that affect the mountain pine beetle, they are the most important identified so far as influencing beetle populations and subsequent tree losses.

The objectives of these guidelines are to describe habits of the beetle in lodgepole pine forest and to present some alternatives that land managers could use to reduce beetle-caused losses. There is no single answer to nor is there a sure cure for the mountain pine beetle problem because biological conditions vary and (most important) management objectives differ. At one time, direct attempts were undertaken to reduce beetle populations over large areas. These control efforts included treating felled and standing trees either by burning or by spraying with toxic chemicals. However, such methods have not effectively prevented subsequent tree losses in large outbreaks, primarily because the stand conditions that permit beetle populations to increase have not changed. Harvesting infested trees prior to brood emergence also has been tried to control beetle populations. Although this method was no more successful than the other methods, it at least utilized a resource that otherwise might have been lost. Our guidelines suggest alternatives that range from "do nothing" to clearcutting a stand, depending upon management's objectives.

To date, all research and development work with the mountain pine beetle and its host has been in unmanaged stands. The association of the beetle to its host in managed stands--stands that are manipulated to grow at or near optimum site capacity--is unknown. Lodgepole stands managed early and growing near optimum capacity will produce trees of large size early and, it is conceivable that under this influence, these fast-growing trees may be less vulnerable to the beetle and may incur less damage than trees of similar size in an unmanaged state. Research is lacking but badly needed in this concept. These guidelines then are applicable only to unmanaged lodgepole pine stands.

THE MOUNTAIN PINE BEETLE—LODGEPOLE PINE INTERACTION

Life Cycle of the Beetle

The mountain pine beetle usually has a single generation per year in lodgepole pine. New adults (fig. 1) emerge and infest living trees in July and August. Some years, emergence and infestation continue into September (fig. 2 and 3).

Vertical egg galleries are constructed in the inner bark and eggs are laid on both sides of the galleries (fig. 4). Larvae feed in the inner bark at right angles to the gallery and girdle the tree (fig. 5). Larvae overwinter and resume development in the spring. Other stages of the beetle are usually not hardy enough to survive winter temperatures. Development is usually completed by midsummer (fig. 6 and 7).

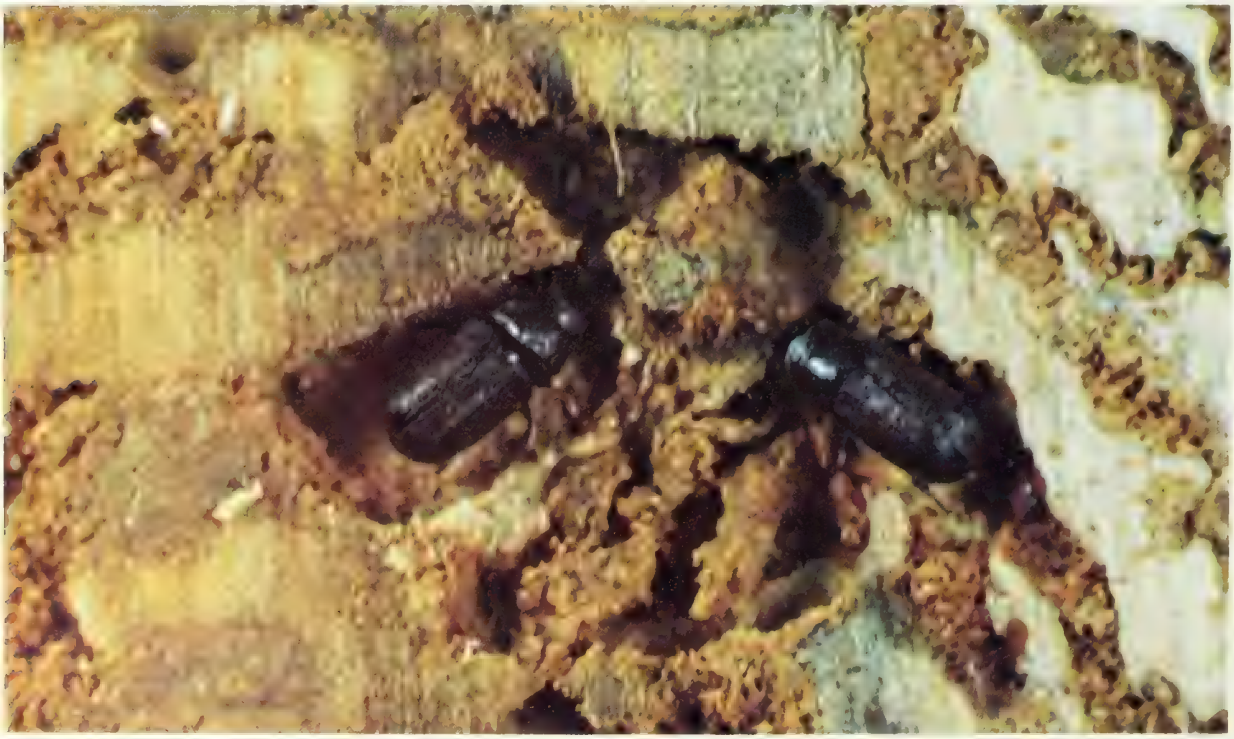


Figure 1.--Adult mountain pine beetles are dark brown to black and average about one-fifth of an inch in length.

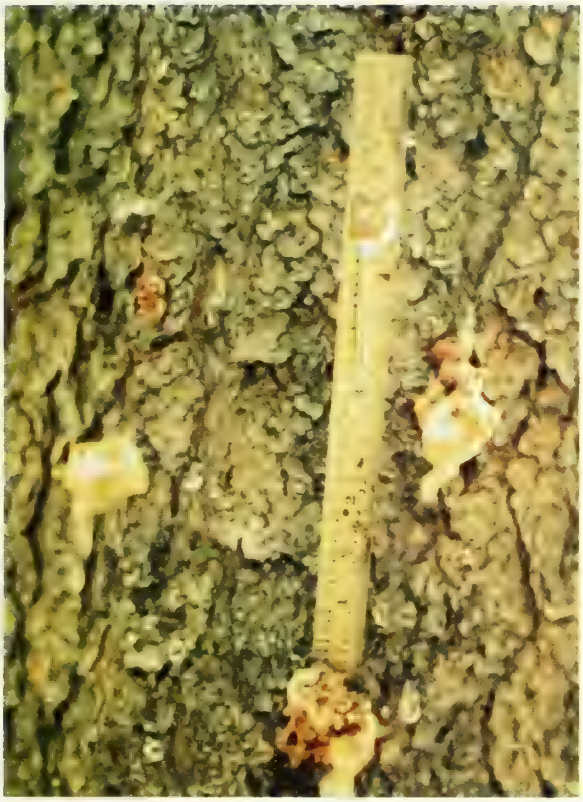


Figure 2.--Pitch tubes on newly infested trees range in color from dark reddish orange to cream; they consist of pitch and particles of bark expelled from the egg gallery by beetles.

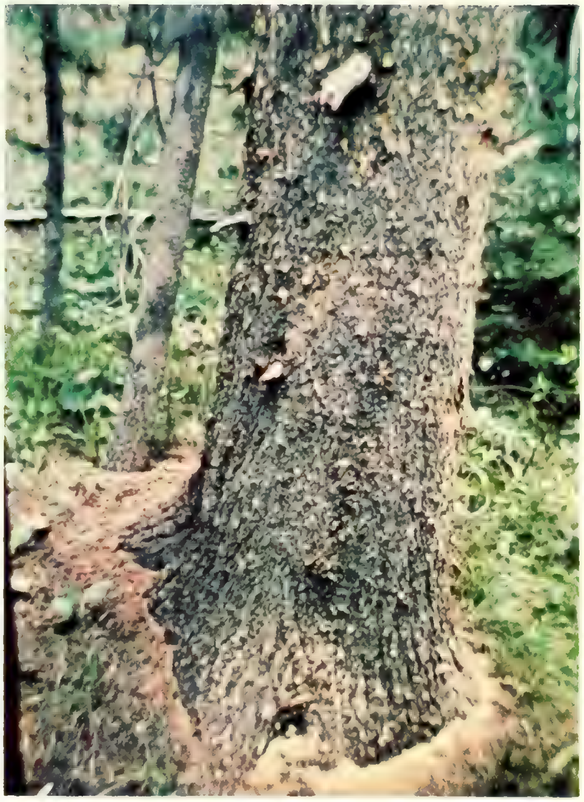


Figure 3.--Orange- to cream-colored particles of bark and wood in crevices and at the base indicate the tree has been infested and killed by beetles.

Considerable variation may occur in the life cycle depending upon local climatic conditions. For example, at low elevations, some beetles may complete a gallery, then emerge from the tree, and attack a second tree. At high elevations, attacks may occur late in the summer but because of cool temperatures most eggs may fail to hatch. Larvae from eggs that do hatch in the fall may require 2 years to become adults, emerge, and infest trees.

Parent beetles introduce several species of blue-stain fungi that invade the xylem. The fungi impede water conduction. Trees having well-developed blue stain tend to dry more rapidly during the fall of the year of attack, but remain more moist the following summer than trees having poorly developed blue stain (fig. 8). Moisture regulation by the fungi appears to be beneficial to developing beetles.

In Canada, resistance to beetle infestation has been equated to the tree's response to artificial infections of blue-stain fungi. Trees that respond to such infections with a copious flow of resin are considered more resistant than trees that respond with a light resin flow. Resistant trees tend to be those having thick phloem. When infested, such trees produce large numbers of beetles and are necessary to foster large epidemics of the beetle. Trees that are easily infected with blue-stain fungi are also easily killed by the beetle; since these are usually trees having thin phloem, they would be expected to produce few beetles.

The needles of infested trees change from green to a yellowish-green in the spring and finally to a bright orange by July (fig. 9) when the new brood is ready to emerge from the tree. Tree losses can be approximated rapidly by estimating the numbers of dead trees from aerial surveys.

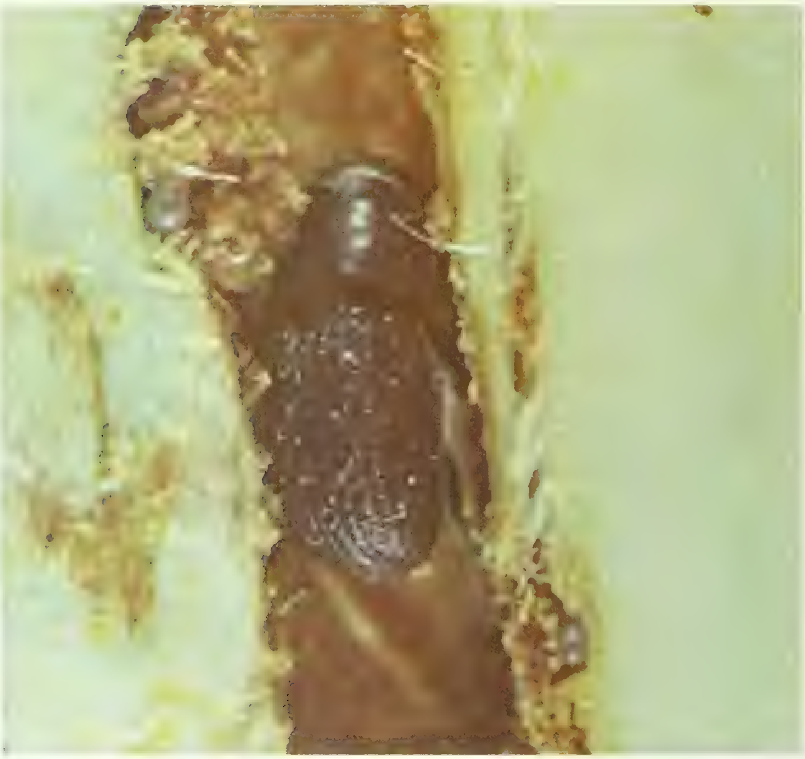


Figure 4.--Vertical egg galleries are made in the bark; eggs are laid in the phloem on alternate sides of the gallery.

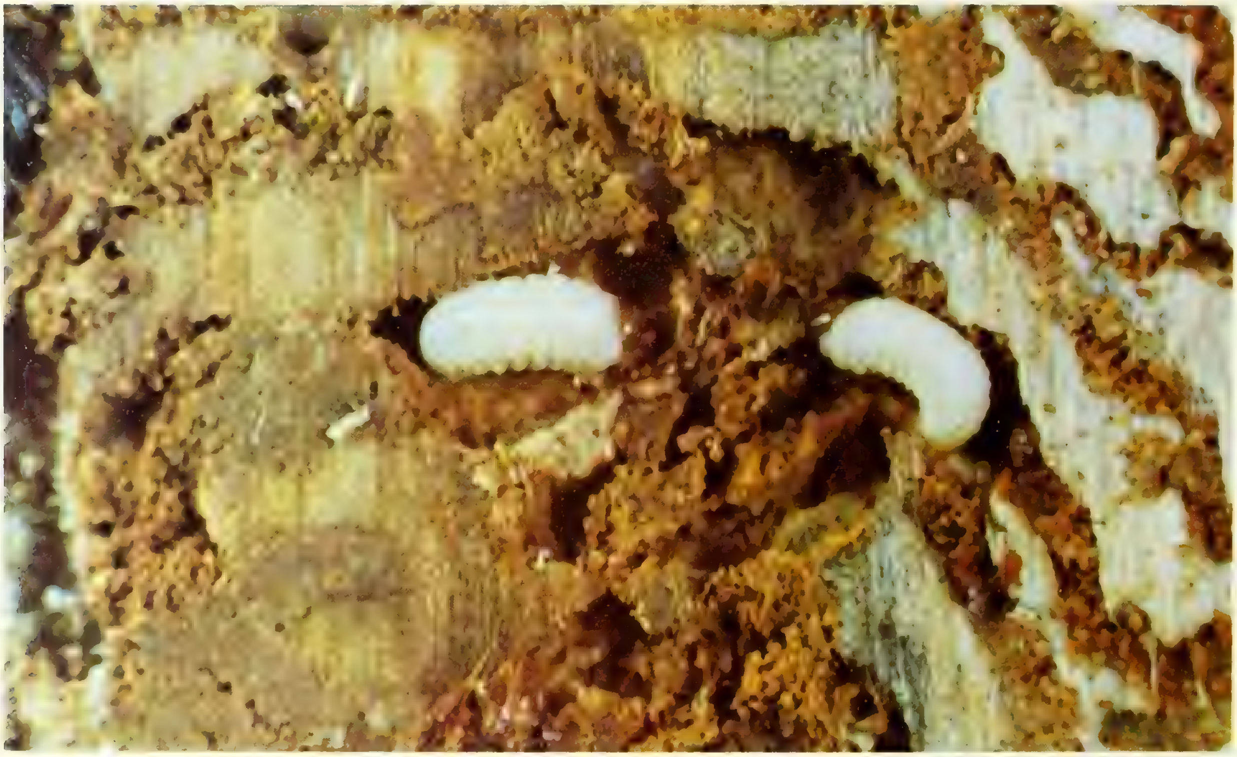


Figure 5.--The white- to cream-colored larvae usually feed at right angles to the egg gallery and girdle the tree. Average length of larvae is one-fourth inch.

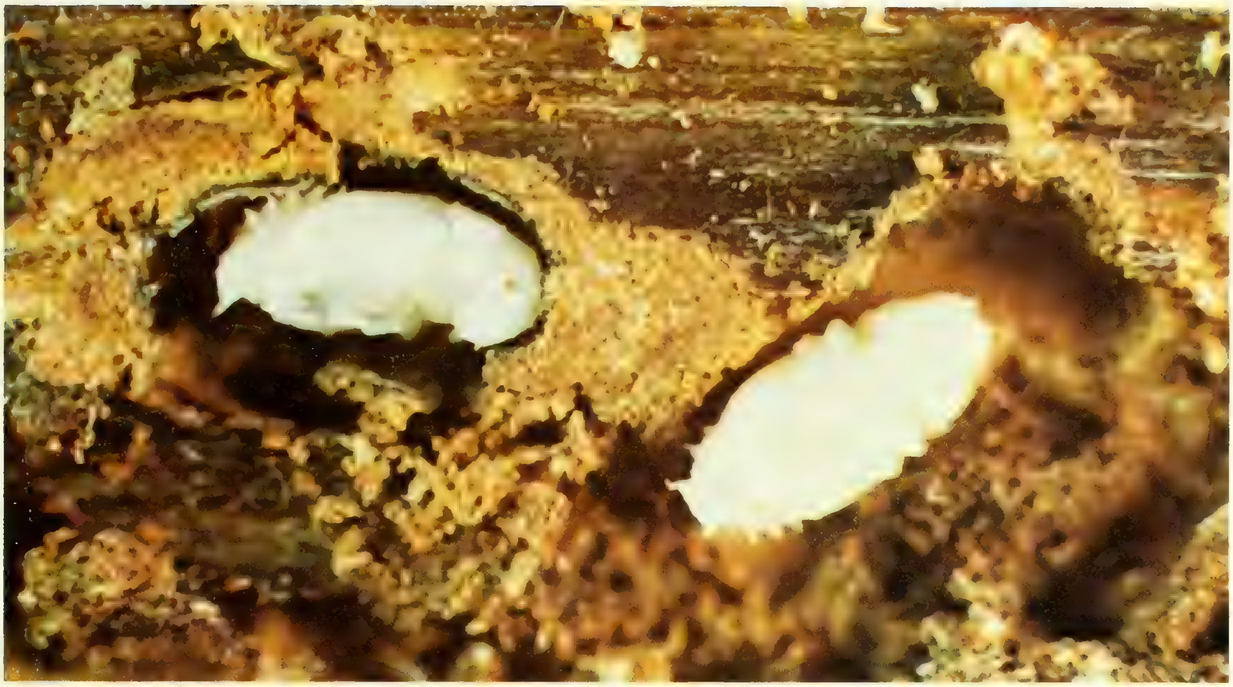


Figure 6.--White- to cream-colored pupae are found in oval cells made by mature larvae. Average length of pupae is one-fifth inch.

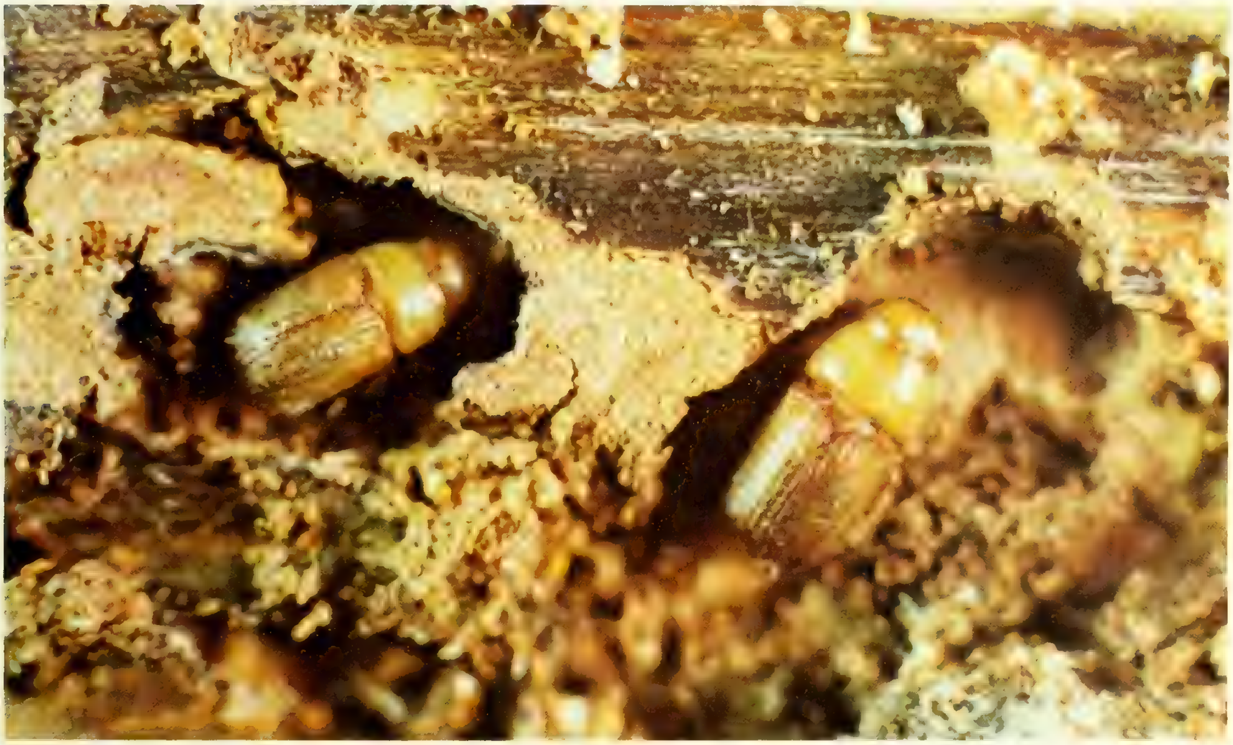


Figure 7.--New adults are light brown to yellow (callow), turning almost black before emerging. Blue-stain fungi can be seen along the edge of the pupal cell containing the beetle on the left. Fungal spores are picked up by the adults when they feed prior to emerging and infesting a green tree. Average length of adults is one-fifth inch.

A

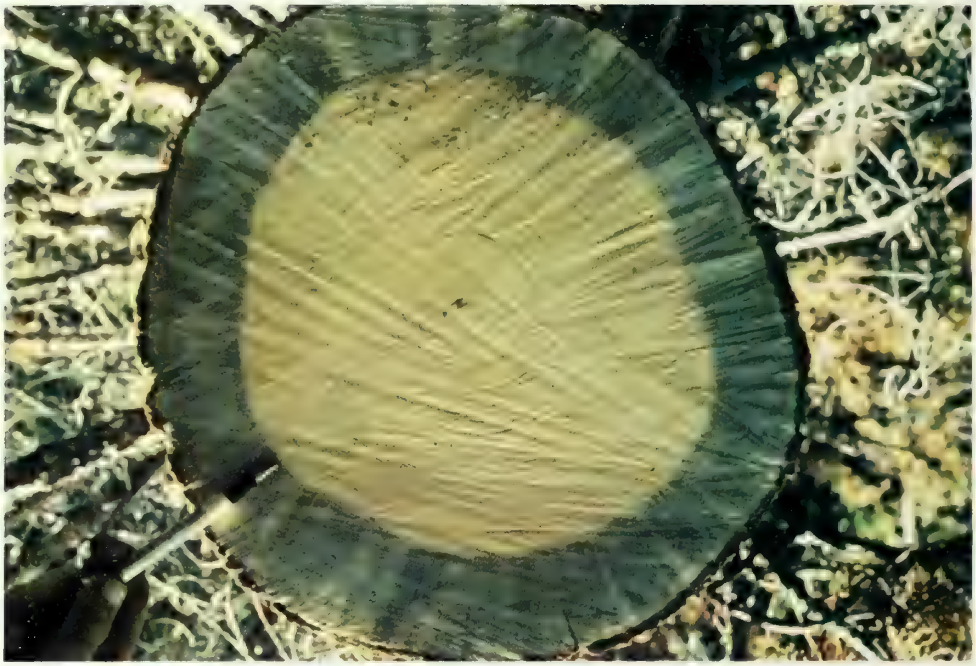
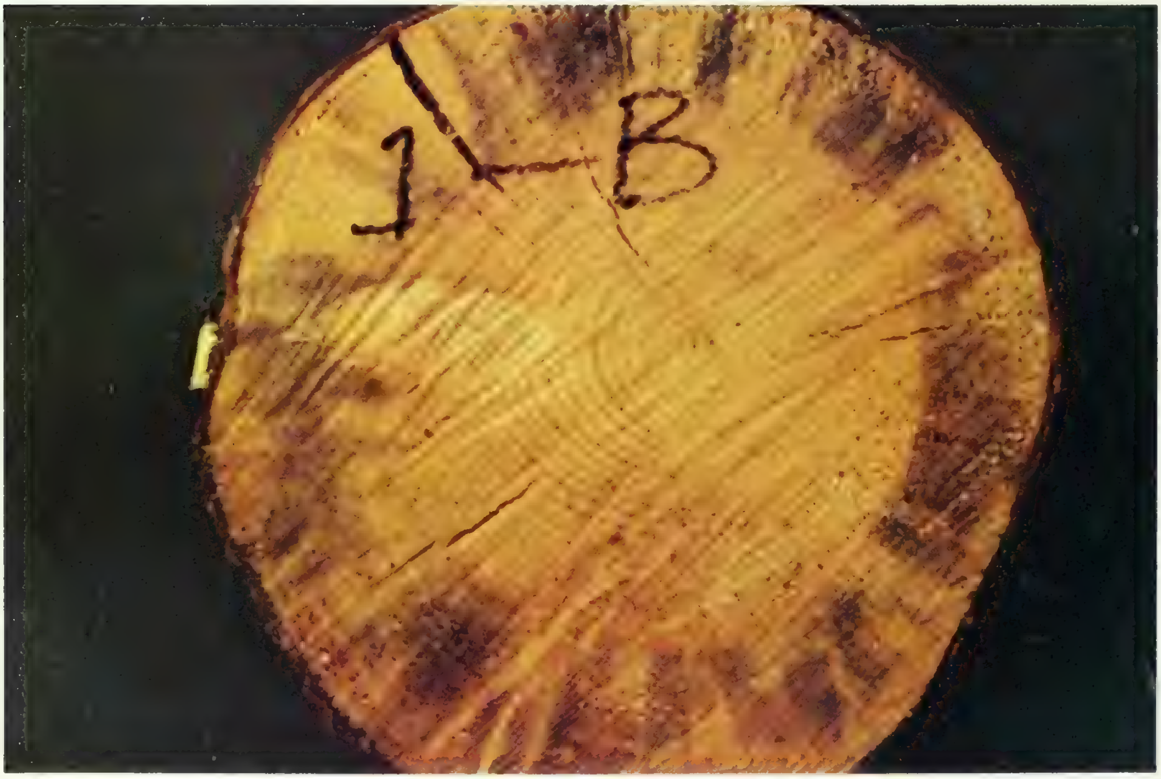


Figure 8.--Blue-staining fungi, carried into the bark by the beetles, discolor the sapwood.
A. Well-developed blue stain usually is uniformly distributed throughout the sapwood.
B. Poorly developed blue stain usually is unevenly distributed in the sapwood.



B

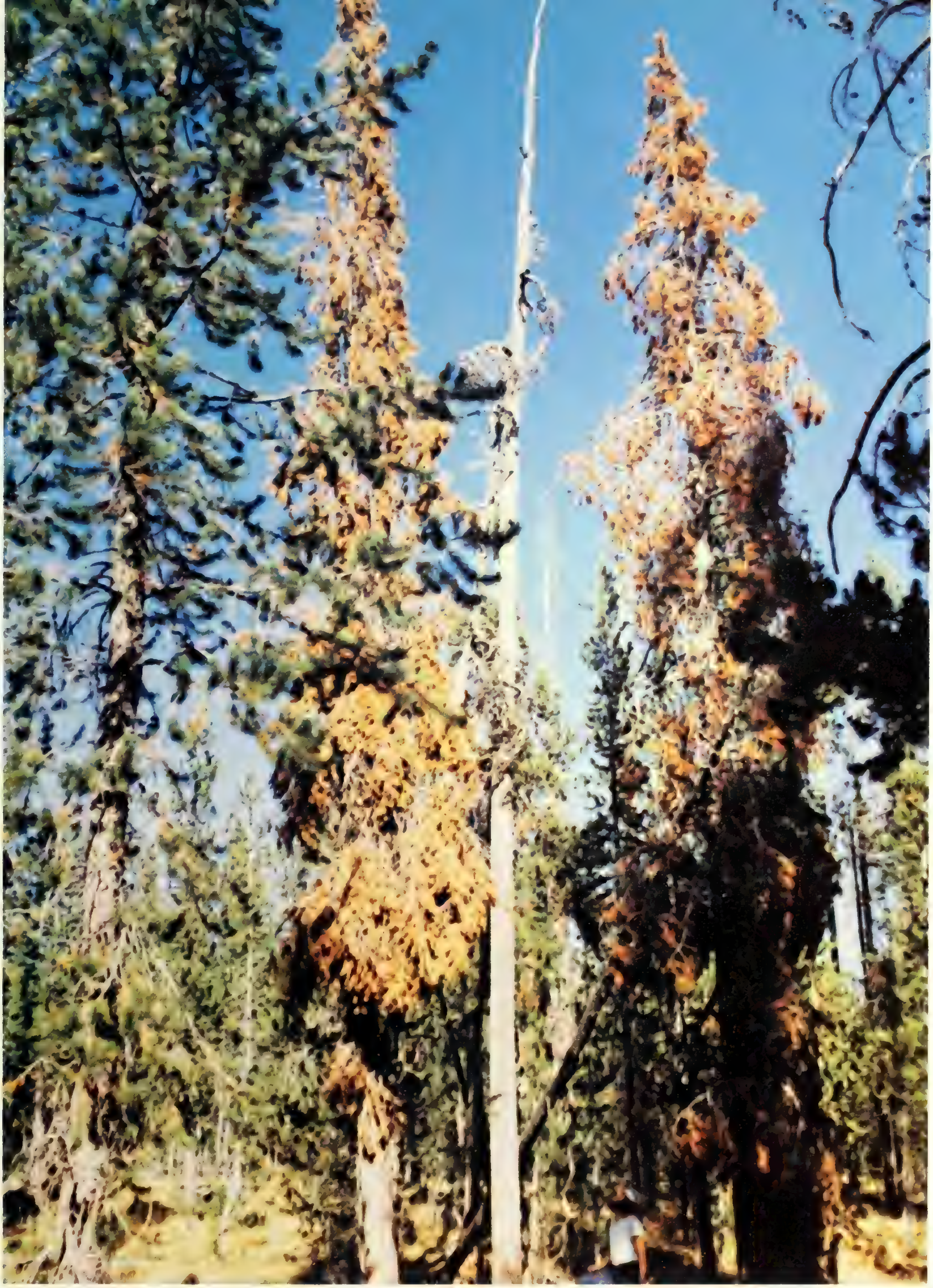


Figure 9.--Needles of infested trees usually change to a bright orange by July when the new brood is ready to emerge from the tree.

Diameter Distribution

The mountain pine beetle kills proportionately more large- than small-diameter trees. Losses range from a small proportion of trees 4 inches d.b.h. to a large proportion of trees over 10 inches d.b.h. (fig. 10). Beetles prefer the largest green trees left in the stand each year as the infestation progresses (fig. 11). After the beetles have killed most large-diameter trees, they infest some of the remaining small-diameter trees. Few beetles mature and emerge from these small trees; so the population declines. Beetle production is low in such trees because of the thin phloem and excessive drying of the tree.

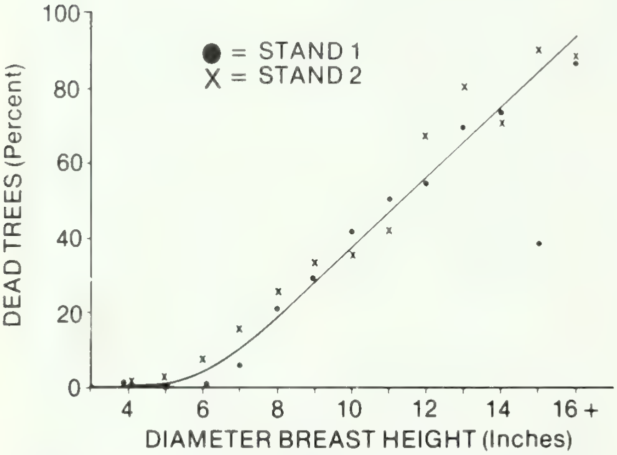


Figure 10.--The mountain pine beetle kills proportionately more large- than small-diameter trees during an infestation.

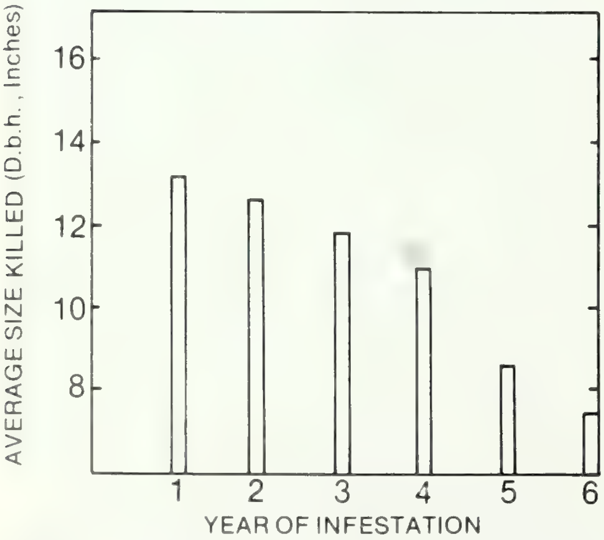


Figure 11.--The beetle usually kills the largest remaining green trees during each successive year of a major infestation.

Phloem Thickness

Phloem is the food of developing larvae. The amount of phloem is one of the most important factors determining the number of larvae that will complete development, become adults, emerge to attack new trees, and establish the next generation (fig. 12). On the average, the thicker the phloem (fig. 13), the greater will be the ratio of brood adults to parents that infested and killed the trees (fig. 14). This ratio will vary according to site quality and stand density as these factors affect phloem thickness.

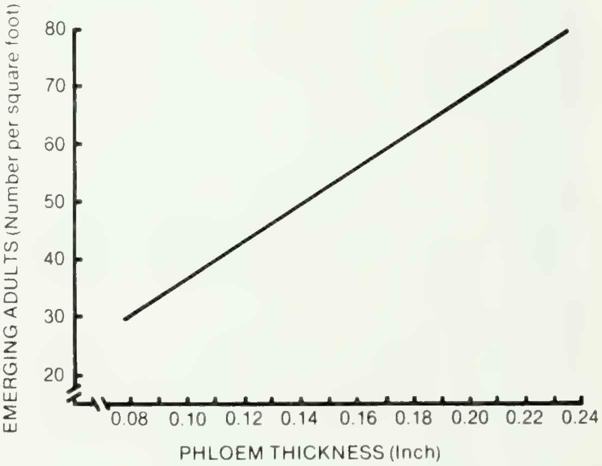


Figure 12.--Beetle production is directly related to thickness of the phloem layer of the infested tree.

Tree Age

Infestations of the beetle seldom develop in stands less than 60 years of age. This is partially due to trees being of small size and generally having thin phloem. The more resinous phloem frequently found in these trees may also be a contributing factor. Trees less than 60 years old, may be infested, but when they are, there is only slight danger that the

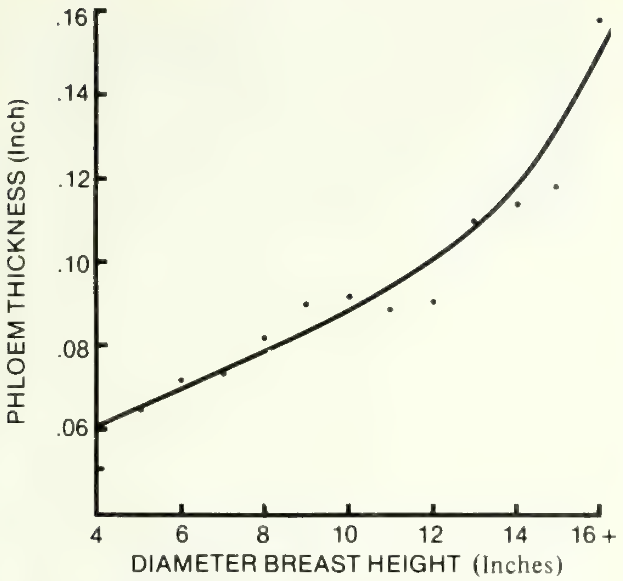


Figure 13.--Phloem is usually thicker in large-diameter trees than in small-diameter trees.

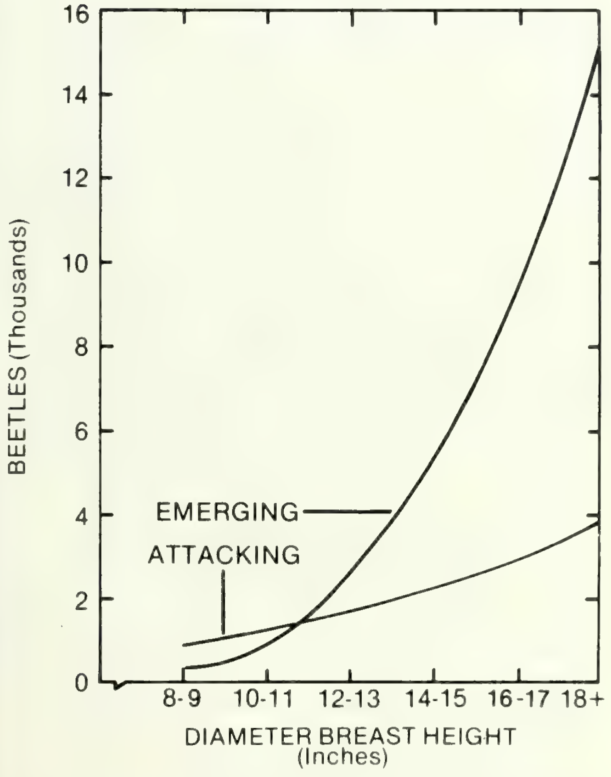


Figure 14.--Generally, the larger the tree, the larger is the ratio of brood adults (emerging) to parents attacking and killing the tree.

outbreak will develop to epidemic proportions. In the 60 to 80 year category, a larger proportion of the trees have reached diameters conducive to more severe and sustained beetle infestation. In these trees, phloem is thicker and its physical and perhaps chemical characteristics are better for beetle development. Stands more than 80 years of age present the greatest potential for beetle infestation. Stands having a large proportion of large-diameter trees with thick phloem are most likely to be infested and will suffer proportionately greater losses.

Stand Density

Density of stands affects growth rate of trees, and hence phloem thickness. Generally, stands having the lowest density have the greatest proportion of large-diameter trees with thick phloem (fig. 15). Because the average phloem thickness is greater, beetle production will be greater in trees of each diameter class in the more open stands (fig. 16). Consequently, losses in these stands will be proportionately greater than those in dense stands.

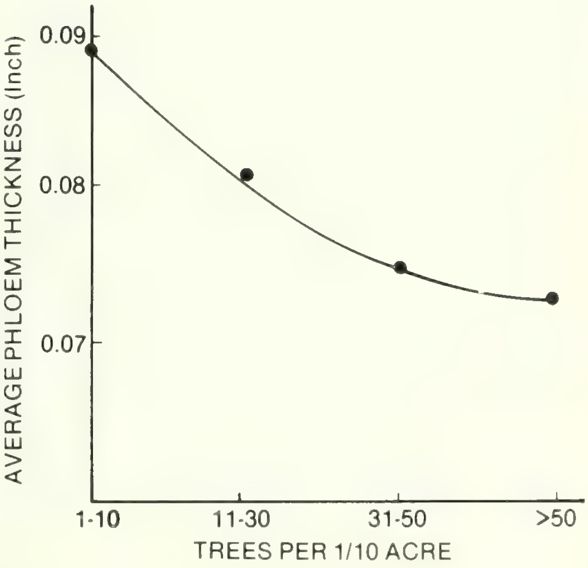


Figure 15.--Trees in dense stands have thinner phloem than those in open stands.

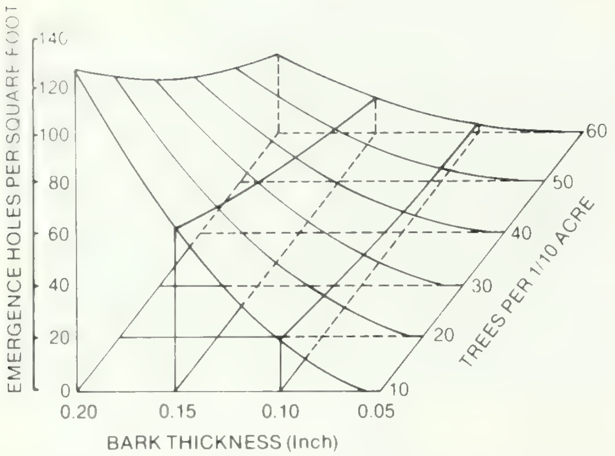


Figure 16.--Beetle production is less in trees of dense stands. Such trees have thinner bark and lower average phloem thickness. Generally, as total bark thickness increases, phloem thickness also increases.

Elevation and Latitude

With increased elevation, tree losses to the mountain pine beetle decline (fig. 17). The cool climate of high elevations so slows beetle development that 2 years may be required for most of the population to complete a single generation. During these long developmental periods, beetle mortality is greater, thus reducing populations more than when a generation is completed in a single year. Slowing of development frequently results in beetles emerging in late summer. Because of the late establishment of egg galleries many eggs fail to hatch before winter. These eggs are killed by cold temperatures. In assessing the effect of temperature on the beetle and its potential to kill trees, both elevation and latitude of the lodgepole pine stand must be considered. Hopkins' Bioclimatic Law[1] has general application.

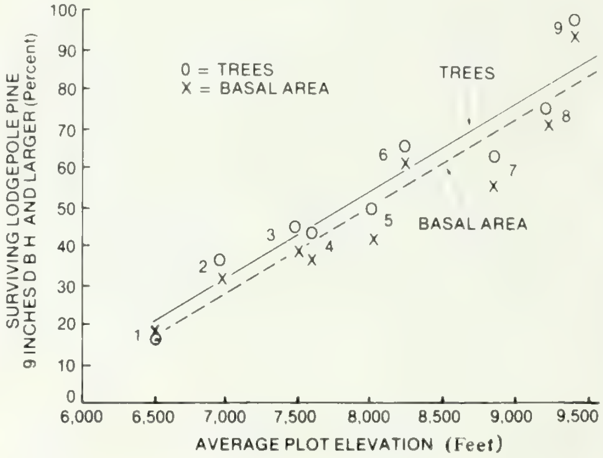


Figure 17.--Tree survival from beetle infestation is directly related to elevation. These data obtained at 44° N. lat., 110° W. long.

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[1] Hopkins' Bioclimatic Law states that variation in seasonal development and habits of plants and animals at different geographical positions within the range of their distribution is at the rate of 4 days for each degree of latitude, 5 degrees of longitude, or 400 feet of elevation.

PREDICTING STAND SUSCEPTIBILITY

Elevation and latitude, age, and average d.b.h. are used in these guidelines to predict stand susceptibility. Phloem has not been included as one of the variables even though it is of primary importance in beetle production at low to middle elevations. However, phloem thickness is generally related to d.b.h. in any given stand of trees and d.b.h. is easier to measure.

In order to be susceptible to a beetle epidemic, a lodgepole pine stand must be located at an elevation and latitude where climate is favorable to the beetle. A general model for determining if a stand lies within a zone of potentially heavy, moderate, or light risk to beetle infestation is presented in figure 18. Even if a lodgepole pine is in an elevation and latitude zone of potentially heavy beetle damage, the stand must meet other requirements for the beetle to be successful. In general, stand age must be 80 years or more, and the average d.b.h. of a stand for trees 5 inches and larger must exceed 8 inches.

By multiplying the following risk factors (1 = low; 2 = moderate; 3 = high) for elevation and latitude, average age, and average d.b.h., the stand's susceptibility classification is obtained; low = 1 to 9; moderate = 12 to 18; high = 27.

Elevation-latitude		*Average age (Years)*		*Average d.b.h. (Inches)*	
High	(1)	<60	(1)	<7	(1)
Moderate	(2)	60-80	(2)	7-8	(2)
Low	(3)	>80	(3)	>8	(3)

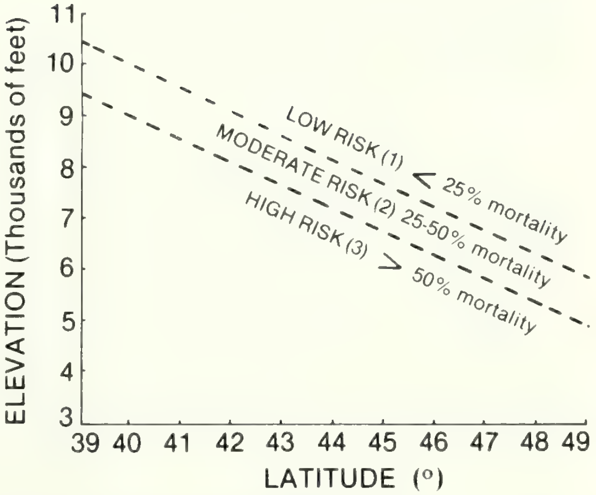

Figure 18.--Risk of mountain pine beetle infestation in lodgepole pine can be defined by zones of elevation and latitude. Percent mortality is for trees 8.5 inches d.b.h. and larger.

For example, when the risk factors for a high elevation stand (risk of 1) more than 80 years old (risk of 3) with an average d.b.h. of 9 inches (risk of 3) are multiplied (1×3×3=9), the stand has a low index for beetle infestation and tree loss because of its elevational location. But, a stand at a low elevation (3) with an average age of 80 (3) and an average d.b.h. of 8.5 (3) has a high index (3×3×3=27) for infestation and subsequent tree loss.

The categories for elevation and latitude, average age, and average d.b.h. have been broadly defined. With additional surveys of infested stands, damage categories may be more precise and perhaps additional ones added.

REDUCING LOSSES TO THE BEETLE

Stands that show a high probability of infestation and subsequent loss to the beetle can be dealt with in several ways, depending upon land-use objectives.

Where Timber Values Are Primary

1. Recognizing that the beetle concentrates heavily on trees of large diameter, continuous lodgepole pine forests can be broken up into small patch cuts, which will result in different age and size classes and so reduce the area likely to be infested at any one time. Then, when a patch reaches high-risk conditions, all trees on the patch can be harvested immediately.

By using a model to predict growth of lodgepole pine in any given stand, the manager can determine when stands of different ages will reach age and size distributions conducive to beetle epidemics. Plans for harvest can be made many years in advance.

2. Since the beetle shows preference for trees of large diameter, partial cuts directed at such trees will greatly reduce infestation potential (fig. 19). Removal of most trees 8 inches d.b.h. and larger would "beetleproof"

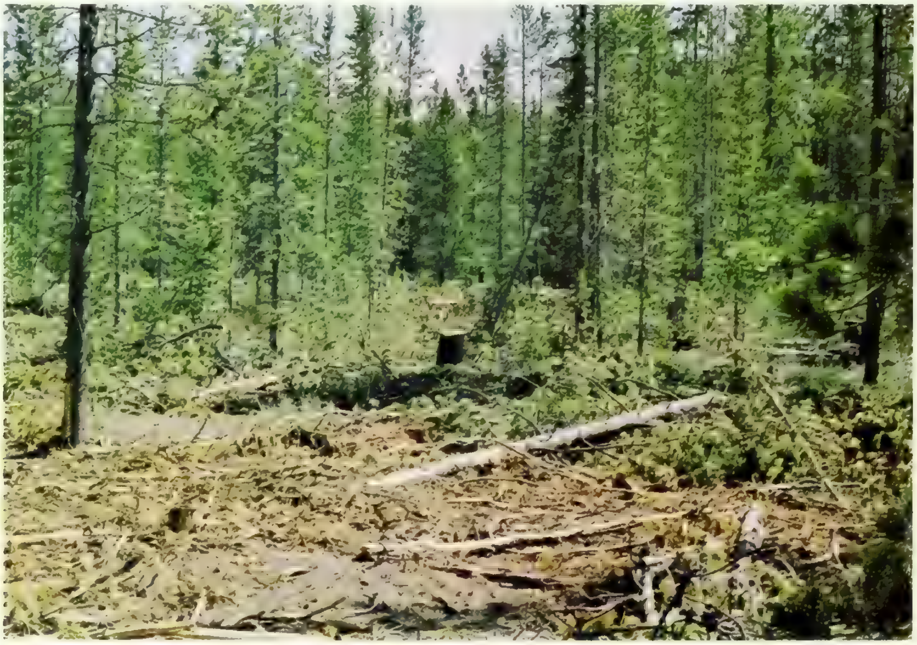

Figure 19.--Removal of large-diameter trees will reduce the infestation index and, consequently, tree losses to the mountain pine beetle.

most stands. However, when partial cuts are to be used, the residual stand should have enough physically vigorous trees to maintain stocking and stand productivity.

Partial cutting may not be the best method to handle beetle problems in understocked stands. In such stands, a large proportion of trees in diameter classes of less than 8 inches may have thick phloem. In those trees, beetle production may continue to be high enough to maintain the infestation, resulting in considerable tree mortality. Clearcutting and regenerating the stand may be the best method of handling high-risk understocked stands.

Problems associated with partial cuts in some stands of lodgepole pine necessitate clearcuts. Windfall in stands opened up by partial cuts can be of particular concern on certain sites. In addition, dwarf mistletoe, *Arceuthobium americanum* Nutt. ex Engelm., is most damaging in stands that have been partially cut, unless the stand is only lightly infected.

3. Harvesting trees before they reach sizes conducive to beetle outbreaks would be an effective method of preventing losses to the beetle where there are markets for material of small diameter. For example, in certain high-risk areas, the manager may elect to grow small trees that meet pole and mine timber requirements.

4. Another management alternative for stands that are particularly susceptible to beetle damage is to favor nonhost trees such as Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. In mixed species forests, the presence of nonhost trees will result in greater residual stocking should an epidemic occur. However, the beetle infests lodgepole pine in mixed species forests just as readily as in pure forests. In addition, the manager also must realize that if he elects to convert lodgepole pine forests to other species, he can expect losses by other insects--the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, if Douglas-fir is favored, and the larch casebearer, *Coleophora laricella* (Hubner), if western larch, *Larix occidentalis* Nutt., is favored However, entomologists generally agree that most insects would prove easier to cope with than the mountain pine beetle, particularly if blocks of nonhost species of trees are interspersed among blocks of lodgepole pine. Then, when any insect infestation occurs, less acreage of host type would be affected.

Where Nontimber Values Are Primary

Forests that are committed to recreation, such as National and State Parks, Wilderness Areas, and other forested land not included in the timber-growing base, may not require action against the beetle. In seral lodgepole pine forest protected from fire, the proportion of other tree species can be expected to increase with each beetle infestation, until succession is complete and both lodgepole pine and the beetle are eliminated from the stand (fig. 20).

Conversion of noncommercial lodgepole pine forests to nonhost species of trees will eliminate the possibility of beetle populations building up and moving from noncommercial to adjacent commercial forested land. In the absence of fire, conversion of lodgepole pine forests can be expected to occur naturally where lodgepole pine is seral, being succeeded by Douglas-fir at lower elevations and subalpine fir, *Abies lasiocarpa* (Hook.) Nutt., and Engelmann spruce, *Picea engelmannii* Parry, at higher elevations. If fire occurs prior to completion of succession, some of these stands will revert to lodgepole pine and another cycle of mountain pine beetle infestations.

In stands where lodgepole pine is climax, periodical infestations of the beetle can be expected as trees in a portion of the stand develop large diameters and thick phloem, conditions needed by the beetle. Openings created in the forest when dominant and codominant trees are killed by beetles are seeded by lodgepole, thus forming an unevenaged, multistoried forest.

In addition to the loss of most large-diameter trees, allowing infestations to run their natural courses will have some positive as well as other negative effects.

Some negative effects.--After an infestation, large numbers of dead trees fall across roads, trails, fences, powerlines, and recrea-

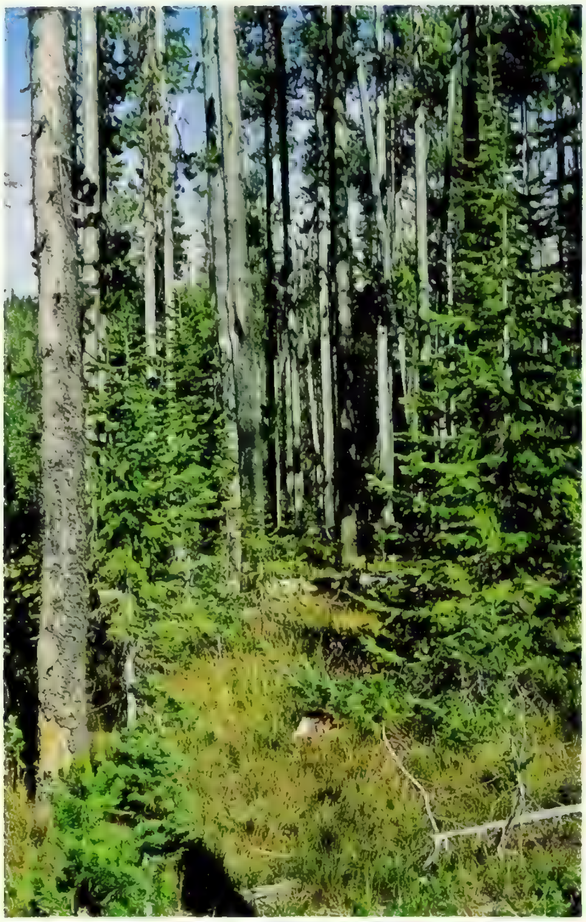

Figure 20.--A mixed lodgepole pine/spruce-fir forest: Natural conversion to nonhost species on land not included in the timber-growing base will eliminate lodgepole pine and the mountain pine beetle.

tional facilities unless they are removed. In addition, there is potential danger from falling trees to hikers, campers, and others using the forests. Fallen trees may limit access of both wild and domesticated animals. Increased fuel loads result in hotter, more destructive fire when fire does occur (fig. 21).

Some positive effects.[2]--Within the 1 to 10-year period following the infestation, snags will provide perches and nesting sites for some raptors and cavity-nesting birds. Fallen trees provide nesting sites and protection for ground-dwelling birds and bedding and cover for black bears, grizzly bears, and squirrels. Shrubs and understory that develop in openings created by loss of trees provide browse, berries, and cover for nesting and foraging birds, bears, and ungulates. The herbaceous understory provides additional forage for both domestic and wild ungulates. Increased water production can also be expected during these 10 years.

Eleven to 30 years after infestation, snags become fewer but downfall increases as decay of the roots and lower boles of dead trees increases. Foraging by bears for grubs and mushrooms increases. Cover and food provided by the understory shrubs peak and begin to decline as dominant pines compete for space. Bird species composition is more diverse. Some understory shrubs begin to succumb to competition from saplings.

After 30 years, snags become uncommon and decay of downfall reduces the problem of access by large ungulates. Rodent cover and logs containing grubs for bears diminish. Shrubs and herbaceous understory are reduced as the canopy of the tree overstory closes. Closing of the canopy results in improved squirrel and ungulate cover.

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[2] Information on effects of mountain pine beetle infestations on wildlife was furnished by Roger S. Bumstead, Wildlife Specialist, Wildlife and Fisheries Staff Unit, Forest Service, Missoula, Montana 59801.

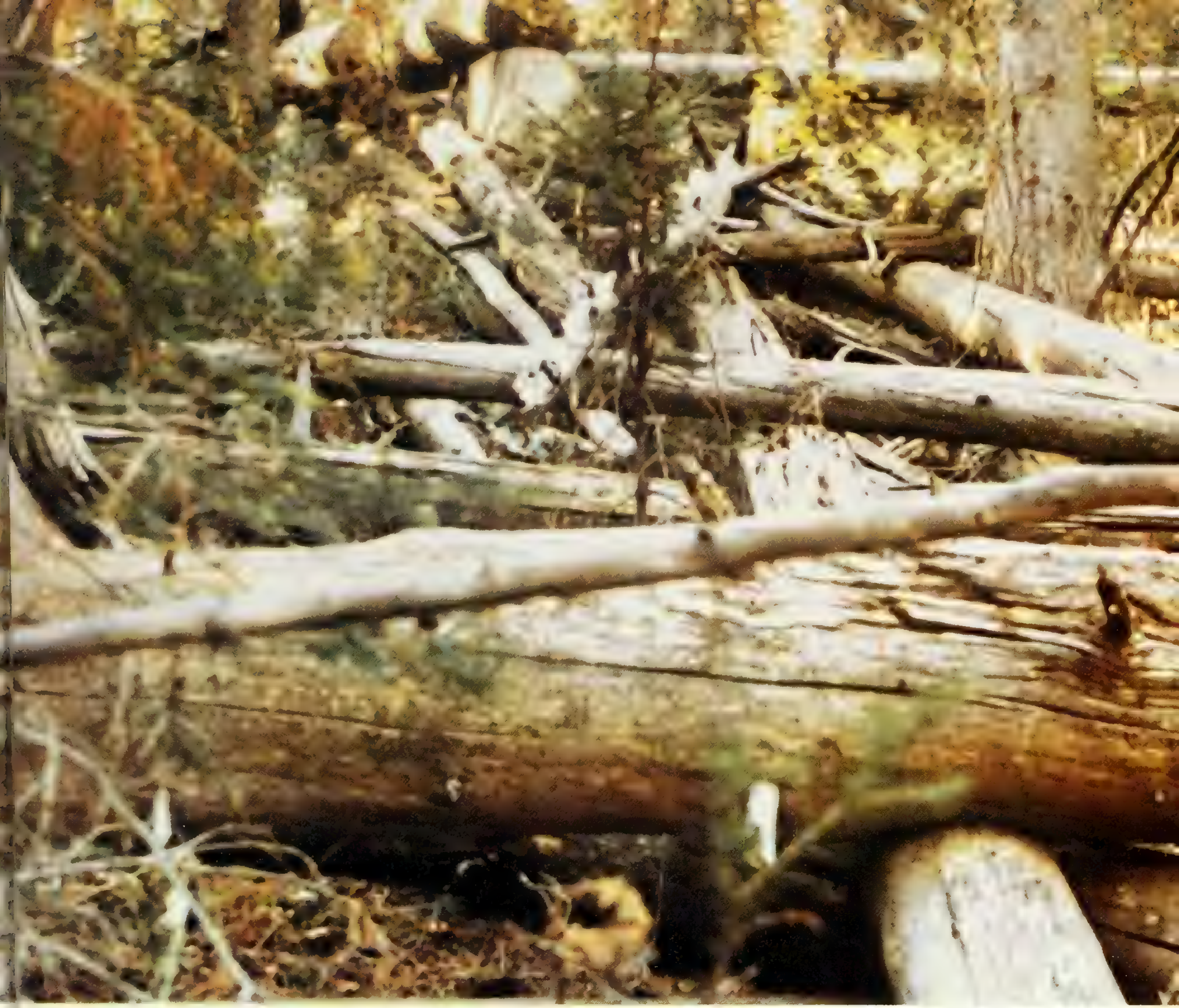

Figure 21.--Fallen trees, mostly lodgepole pines killed during several infestations by the mountain pine beetle, limit access and increase fuel loads.

Where Individual Trees Have High Value

Trees in picnic areas, campgrounds, around visitor centers, and summer and permanent homesites have much higher value than trees in the forest situation. Chemical sprays offer promise for protection of such trees (fig. 22). A single application before flight and attack by beetles has prevented attacks for 1 year and, in some instances, through a second year. The use of such chemicals will vary form State to State. Information on their availability can be obtained from the Forest Insect and Disease Management unit at any of the western Regional Offices or the Washington Office of the Forest Service.

Managers of high-use recreation areas should also consider planting trees of different species where lodgepole pine trees have been killed. Thus, shade and esthetics will be preserved as other lodgepole pines die or are killed by beetles.

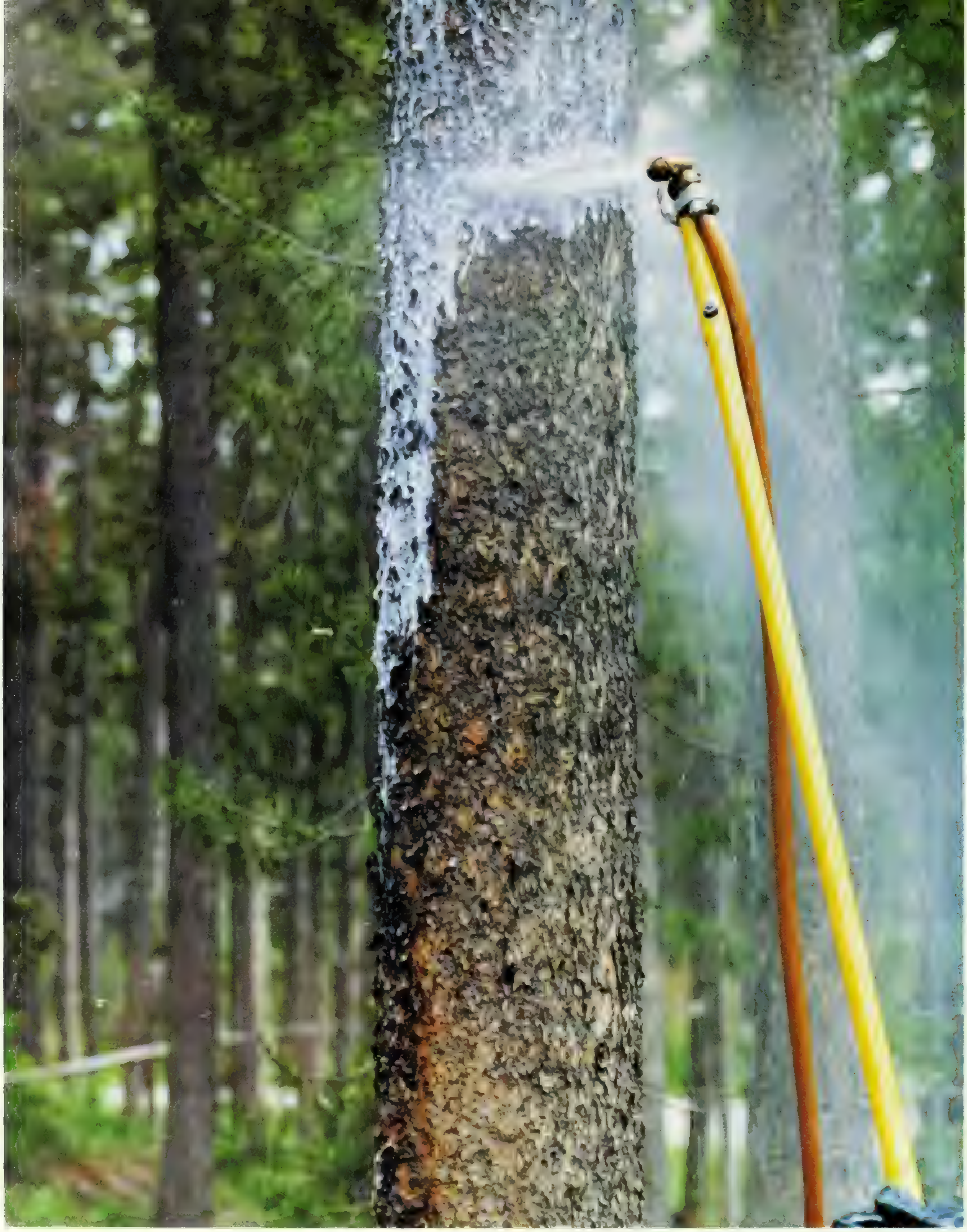

Figure 22.--Trees of high value can be protected by chemical sprays applied before beetles make their attack. (Photo courtesy of Lawrence E. Stipe.)

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Risk of lodgepole pine stands being infested by the mountain pine beetle is determined by average tree diameter, average tree age, and location by elevation and latitude. Methods to reduce losses to the beetle will depend upon land-use objectives. Where the use is timber production, large trees, which have a high risk of infestation, can be removed by either partial or patch cutting. Noncommercial forests do not require action against the beetle. Trees of high value in campgrounds, picnic areas, and near homesites can be protected from infestation by chemical sprays.

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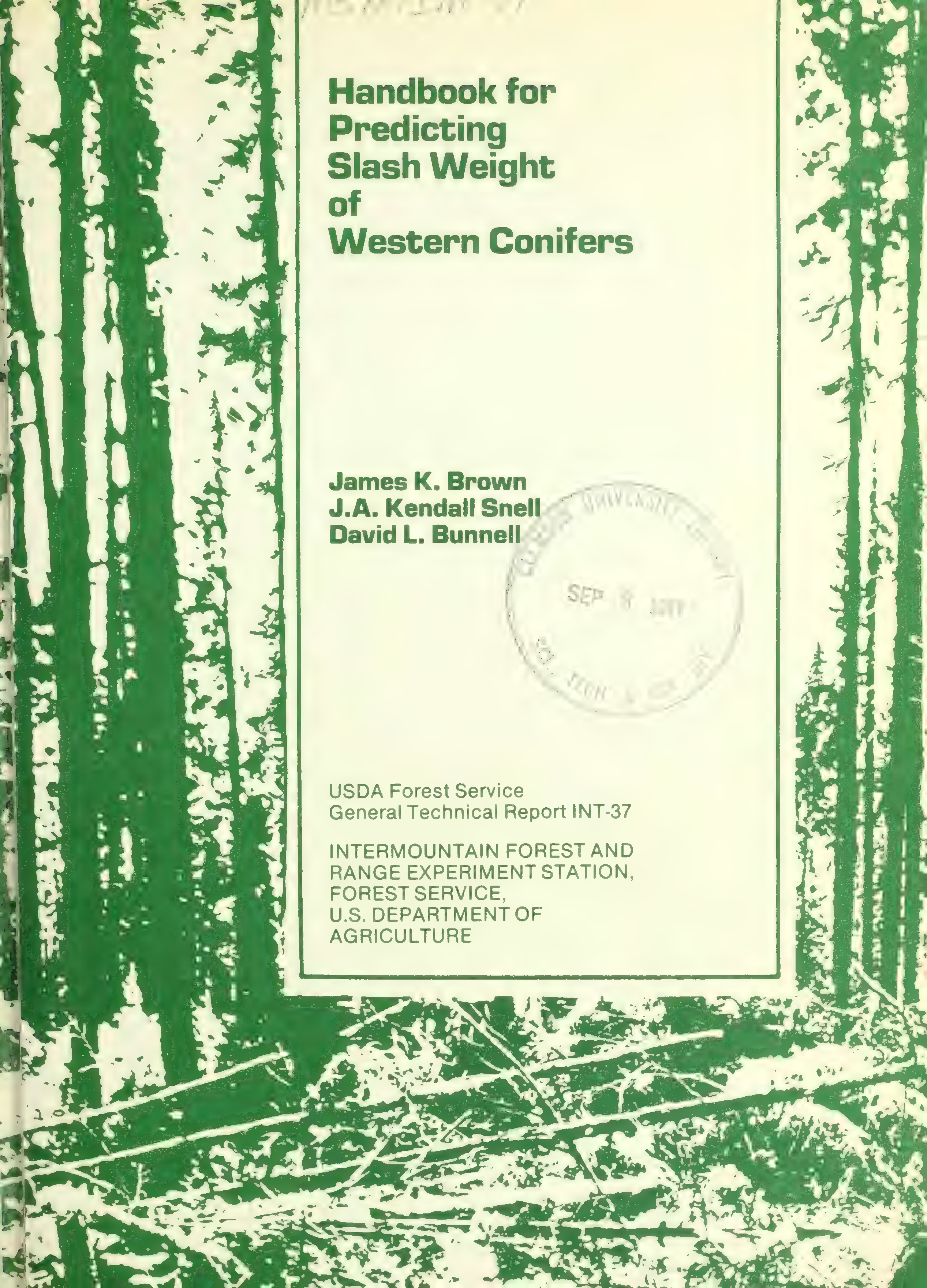

Handbook for Predicting Slash Weight of Western Conifers

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ABSTRACT

As an aid to managing fuel and woody debris, procedures are provided for predicting weights of slash using tables of either slash weight per tree by d.b.h., or slash weight per square foot of tree basal area by d.b.h. Slash weights include crowns (live and dead foliage and branchwood) and unmerchantable bole tips to 3-, 4-, and 6-inch diameter limits. Slash weights can be predicted for material less than and greater than 3 inches in diameter.

CONTENTS

Page

INTRODUCTION. 1

PROCEDURES 3

Sample Prediction 7
Other Species and Crown Classes 7
Slash Weight Per Tree (Tables 1-4) 9
Slash Weight by Basal Area (Tables 5-9) 15

ACCURACY 22

FUEL APPRAISAL 22

How Much Fuel Is Acceptable? 23

BASIS FOR TABLES 24

PUBLICATIONS CITED. 25

APPENDIX I--Fraction of Crowns and Tips 3 Inches and Larger 26

APPENDIX II--Crown Weight Tables 28

APPENDIX III--Crown Component Fractions 30

APPENDIX IV--Unmerchantable Tip Weights 32

TABLES

WEIGHT PER TREE--TOTAL CROWN AND TIP

Table 1.--Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 3-inch top 11

Table 2.--Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 4-inch top 12

Table 3.--Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 6-inch top 13

WEIGHT PER TREE--CROWN AND TIP UNDER 3 INCHES

Table 4.--Weight per tree by d.b.h. of material less than 3 inches diameter for crowns and bole tips 14

Page

WEIGHT PER SQUARE FOOT BASAL AREA--TOTAL CROWN AND TIP

Table 5.--Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 3-inch top 17

Table 6.--Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 4-inch top 18

Table 7.--Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 6-inch top 19

WEIGHT PER SQUARE FOOT BASAL AREA--CROWN AND TIP UNDER 3 INCHES

Table 8.--Weight per square foot of basal area by d.b.h. of material less than 3 inches diameter for crowns and bole tips 20

WOOD DENSITY

Table 9.--Density of wood for selected western species 21

APPENDIX I--FRACTION OF CROWNS AND TIPS 3 INCHES AND LARGER

Table 10.--Fractions of crowns and unmerchantable bole tips that are 3 inches in diameter and larger. 26

APPENDIX II--CROWN WEIGHT TABLES

Table 11.--Crown weight per tree 28

Table 12.--Crown weight per square foot of basal area 29

APPENDIX III--CROWN COMPONENT FRACTIONS

Table 13.--Fraction of crown (live and dead branchwood and foliage) comprised of foliage and branchwood by size classes 30

APPENDIX IV--UNMERCHANTABLE TIP WEIGHTS

Table 14.--Weight of unmerchantable bole tips including wood and bark 32

Table 15.--Height-d.b.h. relationships for trees from a variety of site indexes and stand densities 34

Table 16.--Wood densities, bark densities, bark volume-to-stem volume ratios, and bark weight-to-stem weight ratios used in estimating weights of unmerchantable bole tips 35

INTRODUCTION

This handbook contains procedures for predicting weights of slash--the needles, branches, unmerchantable bole tips, and broken and defective bole material--that remains after timber cutting or thinning. In the past, inability to quantitatively describe downed woody debris such as logging slash has made it difficult to evaluate and communicate debris problems. The capability to predict quantities of slash permits planning for debris problems before they are created. However, predicting slash does not guarantee easy solutions to slash problems, but rather provides a sound foundation for making decisions and formulating plans. Professional experience and good judgment will continue to play important roles in debris management.

Estimates of slash weights can be useful in the following situations:

1. When communicating the magnitude of fuel and debris problems.
2. When writing and administering debris disposal contracts.
3. When describing fiber potential of woody residue.
4. When selecting among debris treatment alternatives like those developed by Roussopoulos and Johnson (1975).
5. When preparing prescriptions for prescribed burning.
6. When appraising potential fire behavior of fuels.

Slash is produced from three portions of trees: (1) crowns (foliage and branches); (2) unmerchantable bole tips; and (3) defective and broken boles (fig. 1). Different methods are required to predict weight of slash from each source. For crowns, the procedures in this handbook are based on predictive relationships between slash weight and tree d.b.h. that were developed from trees sampled in Montana and Idaho (Brown 1976).[1] The relationships for estimating unmerchantable bole tips were developed by Faurot.[2] The procedure for estimating defective and broken boles relies on estimates of merchantable volume, defect, and breakage supplied by users.

---

[1] Brown, James K. Weight and density of crowns of Rocky Mountain conifers. USDA For. Serv. Intermt. For. and Range Exp. Stn. Pap. (in preparation).

[2] Faurot, James L. Tables for estimating stem residues study for ponderosa pine, western larch, Douglas-fir, and lodgepole pine in western Montana. USDA For. Serv. Intermt. For. and Range Exp. Stn. Pap. (in preparation).

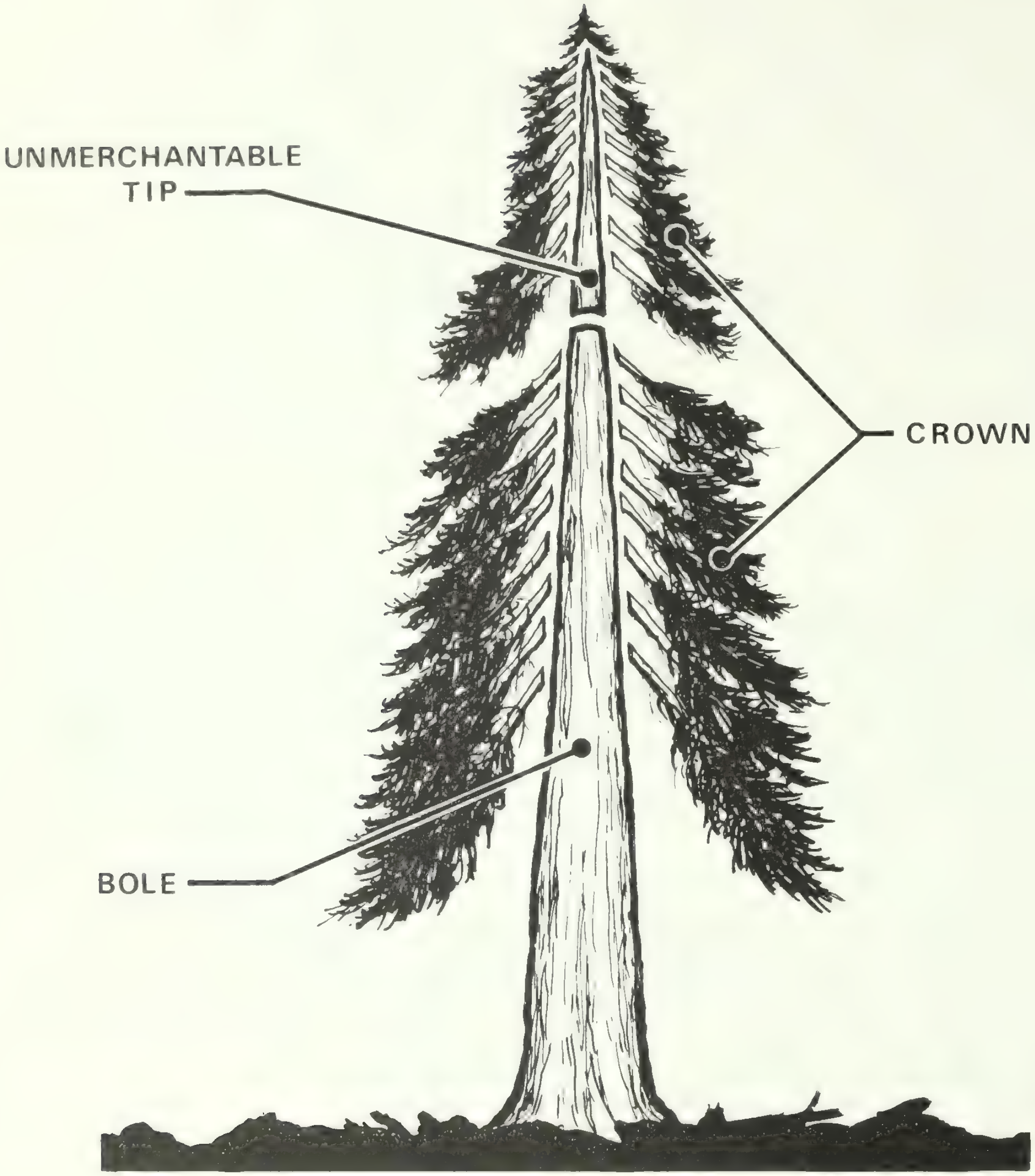


Figure 1.--Different relationships are required to predict weight of slash produced from crowns (foliage and dead and live branchwood), unmerchantable bole tips, and boles (defect and breakage).

Although the data for predicting crown weight were gathered in Montana and Idaho, the predictions should apply reasonably well to trees throughout the western United States except for some coastal areas where tree species of large d.b.h. are found. For a given species and d.b.h., crown weight per tree varies considerably within individual stands. We suspect that variation in crown weight per tree within stands may be about as much as between major forest regions. Thus, slash predictions may be about as accurate outside of the study area as within the area.

Prediction of slash weights for many different species and tree sizes is a logical job for computers. Computer systems for calculating slash potentials based on individual tree inventory data have been developed for some regions of the USDA Forest Service. Where a timber inventory using individual tree records is processed by computer, debris can be predicted by computers. However, computer systems are not readily available to everyone. The procedures in this handbook are for calculating potential slash weights when access to a computer prediction system is unavailable or inconvenient.

The total amount of downed woody fuel following logging or thinning is the sum of downed woody fuels that exist before cutting and slash fuels added by cutting. Existing fuels can be of major importance for evaluating fire potential. Sometimes, existing downed woody fuels weigh as much as or more than the slash created by cutting. (Weight of existing downed woody fuels can be inventoried using procedures described in "Handbook for Inventorying Downed Woody Material" [Brown 1974].)

PROCEDURES

Slash weights can be predicted for trees cut or trampled using estimates of either (1) trees per acre by species and d.b.h., or (2) basal area per acre by species and d.b.h. Tables of slash weight are provided that include crowns (all live and dead foliage and branches) and unmerchantable bole tips to 3-, 4-, and 6-inch diameters. The tables are designed for calculating total crown material and material less than 3 inches in diameter. Usually, crown weight should be computed using tables for total crown and tip material. However, interpreting fire behavior using mathematical fire models such as described in *Users' Guide to Debris Prediction and Hazard Appraisal* (USDA Forest Service Northern Region) requires material less than 3 inches in diameter; therefore, tables for computing crown material less than 3 inches in diameter are also provided.

Slash weight can be predicted and summarized along with existing downed woody fuels as follows:

1. Gather and summarize tree inventory data.
2. Calculate slash weight from cutting and trampling.
3. Calculate slash weight from defect and breakage.
4. If available, add weight of existing fuels to debris summary.

STEP 1. *For any desired area, summarize tree inventory data as number of trees per acre by species and d.b.h. or basal area per acre by species and d.b.h., whichever form is most convenient.*

If possible, summarize the tree data by 1-inch d.b.h. classes as shown on the left-hand side of figure 2. Otherwise, summarize tree data by d.b.h. groups and use the average d.b.h. of each group for determining crown weights. Slash from both cutting and trampling should be considered by including trees in the summary that are expected to be either cut or trampled. (Trampling is the pushing over of small trees by logging equipment.) Trampling probably seldom occurs in thinning operations and may be negligible on many harvesting operations. However, where substantial trampling is expected, its contribution to slash can be predicted by this procedure.

STEP 2. *Select the correct weight table and multiply either the number of trees or basal area per acre times the appropriate table weight for each d.b.h. species category. Sum all weights to obtain the total crown weight per acre (this is shown in the Sample Prediction section, and figure 2).*

For harvest cutting, choose the weight table corresponding to the merchantable tip diameter specified in the timber sale. On sales having mixed merchantable tip diameter specifications use the weight table for either the largest diameter or the diameter associated with the species contributing the most volume.

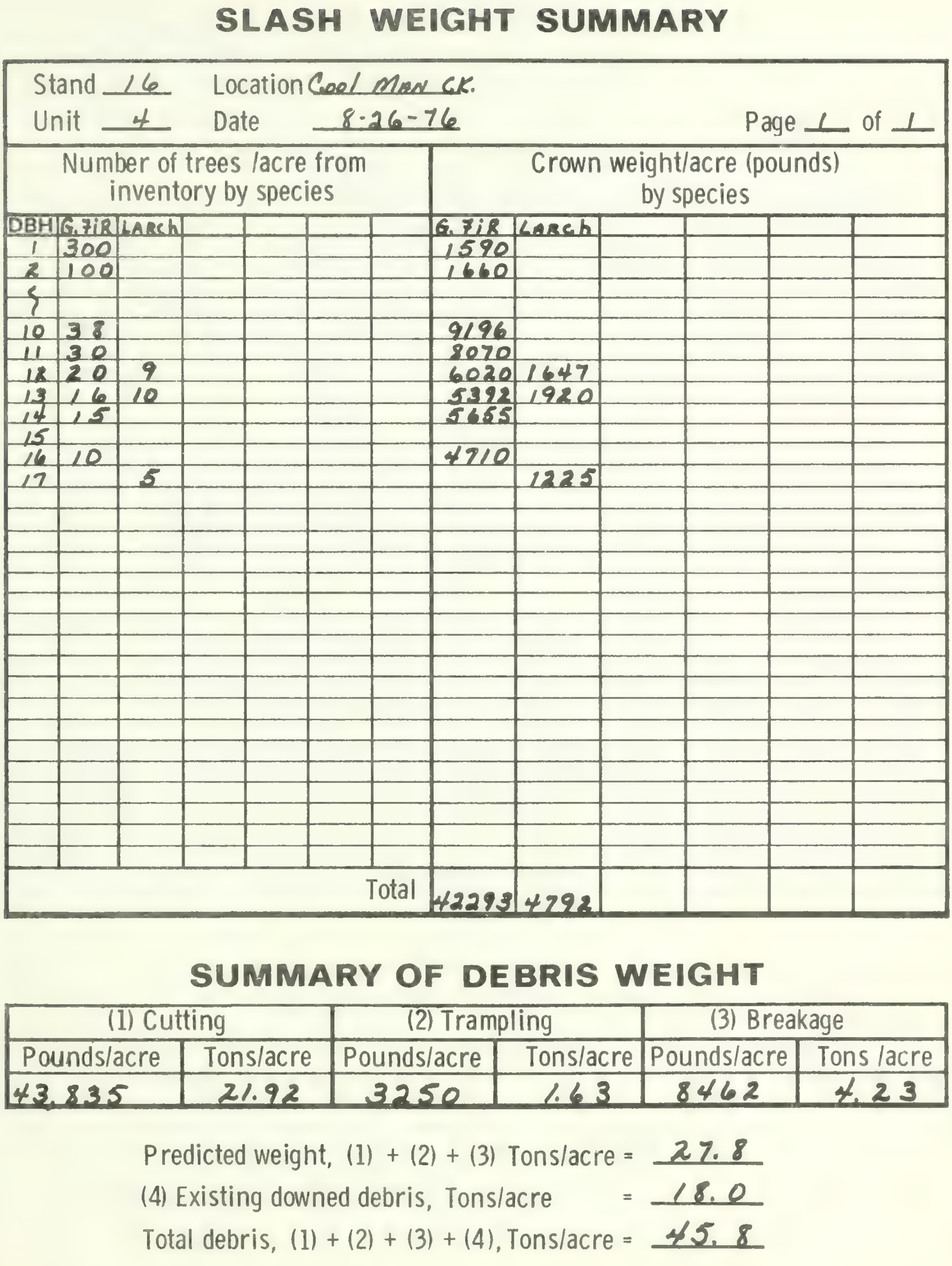
For precommercial thinning and trampling from harvesting activities, use the tables for a 6-inch merchantable tip diameter. These tables permit calculating crown and total bole weights for trees less than 6 inches d.b.h. For trees larger than 6 inches d.b.h. that might be precommercially thinned or trampled, only crown and bole material less than 6 inches is included in the predictions.

The weight tables are as follows:

Table number	*Information to use tables*	*Amount of crown*	*Merchantable tip diameter (inches)*
1	Trees/acre	All	3
2	Trees/acre	All	4
3	Trees/acre	All	6
4	Trees/acre	Less than 3 in	3 and greater
5	Basal area/acre	All	3
6	Basal area/acre	All	4
7	Basal area/acre	All	6
8	Basal area/acre	Less than 3 in	3 and greater

The lines drawn around the weights in the tables show the range of sample tree data. Species and letter codes used in the table heading are as follows:

GF	Grand fir	*Abies grandis* (Dougl.) Lindl.
WL	Western larch	*Larix occidentalis* Nutt.
ES	Engelmann spruce	*Picea engelmannii* Parry
AF	Subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
LP	Lodgepole pine	*Pinus contorta* Dougl.
DF	Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
WH	Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
WP	Western white pine	*Pinus monticola* Dougl.
WC	Western redcedar	*Thuja plicata* Donn
PP	Ponderosa pine	*Pinus ponderosa* Laws.



SLASH WEIGHT SUMMARY

Stand 16 Location Cool Man Ck.
Unit 4 Date 8-26-76 Page 1 of 1

Number of trees /acre from inventory by species							Crown weight/acre (pounds) by species					
DBH	G. FIR	LARCH					G. FIR	LARCH				
1	300						1590					
2	100						1660					
≀												
10	38						9196					
11	30						8070					
12	20	9					6020	1647				
13	16	10					5392	1920				
14	15						5655					
15												
16	10						4710					
17		5						1225				
Total							42293	4792				

SUMMARY OF DEBRIS WEIGHT

(1) Cutting		(2) Trampling		(3) Breakage	
Pounds/acre	Tons/acre	Pounds/acre	Tons/acre	Pounds/acre	Tons /acre
43,835	21.92	3250	1.63	8462	4.23

Predicted weight, (1) + (2) + (3) Tons/acre = 27.8

(4) Existing downed debris, Tons/acre = 18.0

Total debris, (1) + (2) + (3) + (4), Tons/acre = 45.8

Figure 2.--Slash summary form showing a sample estimate of trees expected to be and trampled and the resultant slash. Crown weight per acre is the product of trees per acre and crown weight per tree from table 3. (A sample form in the back of this handbook.)

STEP 3. *Estimate slash weight for defect and breakage as:*

$$w = V \times f \times s/2000 \quad (1)$$

where

w = weight of logging residue from defect and breakage, tons/acre
V = merchantable volume of trees to be cut, ft^3/acre
f = fraction of merchantable volume expected to be left on the ground as defect and breakage
s = density of wood, lb/ft^3

Estimates of merchantable tree volume are obtained from timber cruises or tree inventories. Wood densities for common western species are summarized in table 9. For a mixture of species, densities can be averaged. A wood density value that represents a commonly encountered mixture of western conifer species is 25 pounds per cubic foot.

Slash from defect and breakage is considered to be larger than 3 inches in diameter; thus, weight estimates are needed only when predicting all slash material. The defect and breakage component of slash is far more difficult to predict accurately than weight of crowns and unmerchantable bole tips. Nonetheless, an estimate is possible using experience and knowledge of local harvesting operations. Breakage can vary considerably from negligible in healthy second-growth stands to substantial in defective old-growth stands.

Breakage can be estimated best from local experience with past harvesting operations. In the Northern Rocky Mountains, breakage in old-growth stands is commonly estimated as 10 percent of the cruised merchantable volume and in other stands about 5 percent (opinion of several experienced foresters).

Defect such as rot, crook, sweep, fire scars, butt swell, etc., varies by species and tree size. Most timber sellers have some notion of defect factors (fraction of merchantable volume that is defective) applicable to their area. Not all defect remains on the cutting site because some of it is hauled to the mill. Thus, defect factors must represent the material actually remaining on site. In the Northern Rocky Mountains, about 50 percent of the defective volume remains on an area after cutting (opinion of several experienced foresters).

STEP 4. *To estimate weight of total downed debris, add weight of downed woody material before cutting to predicted weight of slash.*

Sample Prediction

To illustrate procedures for predicting slash, consider a partial cutting of grand fir and larch. The merchantable tip diameter limit is 6 inches and number of trees per acre is used to calculate weight for all slash material. Weights summarized by source of material are:

Source	*Weight (tons/acre)*
Cutting: Trees to be cut are grand fir (10 to 16 in d.b.h.); and larch (12 to 17 in d.b.h.). Number of trees per acre (recorded in figure 2) multiplied times crown weights per tree (from table 3) provided the slash weights shown in figure 2.	21.92
Trampling: Trees expected to be trampled were 1 and 2 in d.b.h. Weights were calculated using table 3	1.63
Defect and breakage: $w = 3{,}385 \times 0.10 \times 25/2{,}000$. A timber cruise showed a volume of 3,385 ft^3, of which 80 percent was grand fir. A wood density of 25 lb/ft^3, was determined by weighting the densities of grand fir and larch from table 9 by their percentages of total timber volume: (80 percent × 23.1 + 20 percent × 32.4)/100 = 25.0. Breakage was judged to be about 5 percent and defect left on site was 5 percent. Thus, the f in equation (1) is 0.05 plus 0.05 or 0.10.	4.23
Predicted slash	27.8
Downed woody material: Inventory of existing downed debris yielded 18 tons/acre	18.0
Total	45.8

Other Species and Crown Classes

These procedures can be used with unknown but probably acceptable accuracy on species having branch forms similar to species that are listed. To indicate accuracy of prediction, crown weight for species in this handbook that have similar branch forms, such as the firs and spruce, were compared. On the average, one species was within about 20 percent of the other. For some d.b.h.'s, differences were as high as 50 percent. The following combinations of species are probably similar enough to yield reasonably accurate slash predictions when considered alike:

Listed in tables	*Not listed in tables*
Lodgepole pine	White barked pine, limber pine
Grand fir	Pacific red fir

The tables in this handbook were developed from data for trees having dominant and codominant crown classes. Brown (see footnote 1) found that for shade-tolerant species, crown weight of intermediate crowns is not significantly different from dominant and codominant crowns. However, for shade-intolerant species, weight of intermediate crowns is significantly less than for dominant and codominant crowns. Thus, in stands of intolerant species where a large proportion of the trees have intermediate crowns, an adjustment of the crown weight based on dominant and codominant crowns may be desirable.

We recommend adjusting crown weights only for ponderosa pine, lodgepole pine, and western larch. When these species dominate the composition and have a high proportion of intermediate crowns, adjusted crown weights can be calculated as follows:

D.b.h.	*Equation*	
Less than 7.5 in	$D' = D(1 - 0.5\ f_I)$	(2)
7.5 in and greater	$D' = D(1 - 0.4\ f_I)$	(3)

where

D' = crown weight per acre adjusted for intermediate crowns
D = crown weight per acre based on dominant and codominant crowns
f_I = fraction of trees per acre having intermediate and suppressed crowns

Slash Weight (lbs) per TREE

WEIGHT PER TREE--TOTAL CROWN AND TIP

TABLE 1.--*Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 3-inch top*

3-INCH TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
4	35	29	31	40	45	37	34	40
5	48	36	36	51	60	47	44	53
6	66	46	43	64	77	61	56	69
7	87	59	52	80	97	79	70	87
8	113	74	62	97	120	100	86	108
9	143	92	72	116	146	125	104	131
10	177	112	84	137	175	154	124	156
11	216	133	97	160	207	187	145	183
12	259	155	110	184	242	226	168	213
13	307	179	125	210	281	269	193	246
14	359	205	140	239	324	319	220	280
15	416	233	156	269	370	375	249	317
16	478	262	173	301	422	437	280	357
17	544	293	190	334	477	489	312	399
18	616	325	209	380	538	546	347	444
19	692	360	228	429	587	607	383	492
20	774	396	248	482	637	671	421	542
21	861	433	268	537	688	739	462	596
22	953	473	289	597	741	809	504	652
23	1,050	513	311	659	796	883	549	712
24	1,150	556	334	725	852	960	595	775
25	1,260	600	357	795	909	1,040	644	841
26	1,370	645	382	869	968	1,120	695	911
27	1,490	693	406	946	1,030	1,210	748	985
28	1,620	741	432	1,030	1,090	1,300	804	1,060
29	1,750	792	458	1,110	1,150	1,400	862	1,140
30	1,890	844	485	1,200	1,220	1,490	922	1,230
31	2,030		513	1,290	1,280		985	1,320
32	2,180		541	1,390	1,350		1,050	1,410
33	2,330		570	1,490	1,420		1,120	1,510
34	2,490		600	1,600	1,490		1,190	1,610
35	2,660		630	1,710	1,560		1,260	1,720
36	2,830		661	1,820	1,630		1,340	1,830
37	3,010		693	1,940	1,700		1,410	1,950
38	3,200		725	2,060	1,780		1,500	2,070
39	3,390		758	2,190	1,850		1,580	2,200
40	3,590		792	2,320	1,930		1,670	2,330

TABLE 2.--*Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 4-inch top*

4-INCH TOP

D.b.h. (inches)	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Species							
	Pounds							
5	67	55	60	70	77	62	61	68
6	82	62	63	81	92	74	70	82
7	101	72	69	94	111	90	83	99
8	126	86	77	110	132	110	98	118
9	154	103	87	128	157	134	115	140
10	188	122	98	148	185	162	134	165
11	226	142	109	170	217	195	155	192
12	268	164	122	194	252	233	177	222
13	315	187	136	220	290	276	202	253
14	367	213	151	248	333	325	229	288
15	424	240	166	277	379	381	257	325
16	485	269	183	309	430	444	288	364
17	552	299	200	342	486	495	320	406
18	623	332	218	388	546	552	354	451
19	699	366	237	437	595	613	390	498
20	780	401	257	489	645	677	428	549
21	867	439	277	544	696	744	469	602
22	959	478	298	603	749	814	511	658
23	1,060	518	320	666	803	888	555	718
24	1,160	561	342	732	859	965	602	781
25	1,270	605	366	802	916	1,050	650	847
26	1,380	650	390	875	975	1,130	701	917
27	1,500	697	414	952	1,040	1,220	754	990
28	1,620	746	440	1,030	1,100	1,310	810	1,070
29	1,760	796	466	1,120	1,160	1,400	868	1,150
30	1,890	848	493	1,210	1,220	1,500	928	1,230
31	2,030		520	1,300	1,290		990	1,320
32	2,180		549	1,400	1,360		1,060	1,420
33	2,340		578	1,500	1,420		1,120	1,510
34	2,500		607	1,600	1,490		1,190	1,620
35	2,660		637	1,710	1,560		1,270	1,720
36	2,840		668	1,830	1,640		1,340	1,840
37	3,020		700	1,950	1,710		1,420	1,950
38	3,200		732	2,070	1,780		1,500	2,080
39	3,390		766	2,200	1,860		1,580	2,200
40	3,590		799	2,330	1,940		1,670	2,340

TABLE 3.--*Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 6-inch top*

6-INCH TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	3.3	2.5	3.5	5.5	5.3	10.6	4.0	5.1
2	10.5	10.2	11.3	16.5	16.6	17.3	13.4	15.3
3	22.8	24.4	27.7	33.1	34.4	31.5	28.7	29.1
4	40	45	56	55	60	56	51	46
5	64	73	99	82	93	93	80	66
6	93	107	162	113	136	145	118	88
7	181	158	173	176	187	151	157	165
8	195	158	167	182	200	163	163	177
9	216	165	166	192	218	182	173	193
10	243	177	169	206	242	205	187	213
11	276	191	175	223	269	235	204	236
12	315	207	183	243	301	270	223	262
13	359	227	192	266	337	311	245	292
14	408	249	203	291	377	358	270	324
15	462	273	216	318	421	412	296	359
16	521	299	230	348	471	472	325	397
17	586	328	245	379	525	523	355	437
18	655	358	261	423	584	579	388	481
19	730	391	278	471	632	638	423	527
20	810	425	296	522	681	701	460	576
21	896	461	315	576	731	767	500	629
22	987	499	335	634	783	837	541	684
23	1,080	538	356	696	837	910	585	743
24	1,180	580	377	761	892	987	630	805
25	1,290	623	399	830	949	1,070	678	871
26	1,400	667	423	902	1,010	1,150	729	940
27	1,520	714	446	979	1,070	1,240	781	1,010
28	1,650	761	471	1,060	1,130	1,330	836	1,090
29	1,780	811	497	1,140	1,190	1,420	893	1,170
30	1,910	862	523	1,230	1,250	1,520	953	1,250
31	2,060		550	1,320	1,320		1,020	1,340
32	2,200		577	1,420	1,390		1,080	1,440
33	2,360		606	1,520	1,450		1,150	1,530
34	2,520		635	1,630	1,520		1,220	1,640
35	2,680		665	1,740	1,590		1,290	1,740
36	2,860		695	1,850	1,660		1,360	1,860
37	3,040		726	1,970	1,740		1,440	1,970
38	3,220		758	2,090	1,810		1,520	2,100
39	3,410		791	2,220	1,890		1,610	2,220
40	3,610		824	2,350	1,960		1,690	2,360

WEIGHT PER TREE--CROWN AND TIP UNDER 3 INCHES

TABLE 4.--*Weight per tree by d.b.h. of material less than 3 inches diameter for crowns and bole tips*

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	3.1	2.4	3.4	5.3	5.2	10.4	3.9	4.9
2	9.8	9.4	10.5	15.5	15.9	16.6	12.5	14.4
3	16.3	14.2	16.1	22.8	25.9	22.9	19.0	22.9
4	35	29	31	40	45	37	34	40
5	48	36	36	51	60	47	44	53
6	66	46	43	64	77	61	56	69
7	87	59	52	80	97	79	70	87
8	111	74	62	97	120	100	86	108
9	139	92	72	116	146	125	104	131
10	170	112	84	137	175	154	124	156
11	205	133	96	160	207	187	145	183
12	243	155	109	184	242	226	168	213
13	284	179	122	210	281	269	193	246
14	328	205	137	239	324	319	220	280
15	376	233	152	268	370	375	249	317
16	426	262	168	299	422	437	280	357
17	480	293	184	332	477	489	312	399
18	536	325	201	377	538	546	347	444
19	596	360	219	425	587	607	383	492
20	658	396	238	476	637	671	421	542
21	723	433	257	530	688	739	462	596
22	790	473	277	588	741	809	504	652
23	861	513	298	649	796	883	549	712
24	933	556	320	713	852	960	595	775
25	1,010	600	342	781	909	1,040	644	841
26	1,090	645	364	852	968	1,120	695	911
27	1,170	693	388	926	1,030	1,210	748	985
28	1,250	741	412	1,000	1,090	1,300	804	1,060
29	1,330	792	436	1,090	1,150	1,400	862	1,140
30	1,420	844	462	1,170	1,220	1,490	922	1,230
31	1,510		488	1,260	1,280		985	1,320
32	1,600		514	1,350	1,350		1,050	1,410
33	1,690		542	1,450	1,420		1,120	1,510
34	1,780		570	1,550	1,490		1,190	1,610
35	1,880		598	1,660	1,560		1,260	1,720
36	1,980		627	1,760	1,630		1,340	1,830
37	2,080		657	1,880	1,700		1,410	1,950
38	2,180		688	1,990	1,780		1,500	2,070
39	2,280		719	2,120	1,850		1,580	2,200
40	2,380		751	2,240	1,930		1,670	2,330

Slash Weight (lbs) by BASAL AREA

TABLE 5.--*Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 3-inch top*

3-INCH TOP

D.b.h. inches	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
4	402	332	355	463	520	419	390	455
5	353	264	266	375	438	346	321	387
6	334	235	221	328	392	312	284	349
7	326	220	195	298	364	294	262	325
8	324	212	177	277	344	286	246	308
9	324	208	164	262	330	282	235	295
10	325	206	154	251	320	282	227	286
11	327	201	147	242	313	284	220	278
12	330	198	141	234	308	287	214	272
13	333	194	135	228	305	292	210	266
14	336	192	131	223	303	298	206	262
15	339	190	127	219	302	305	203	259
16	342	188	124	215	302	313	200	256
17	345	186	121	212	303	310	198	253
18	349	184	118	215	305	309	196	251
19	352	183	116	218	298	308	195	250
20	355	181	113	221	292	308	193	249
21	358	180	111	223	286	307	192	248
22	361	179	110	226	281	307	191	247
23	364	178	108	228	276	306	190	247
24	367	177	106	231	271	306	189	247
25	370	176	105	233	267	305	189	247
26	373	175	103	236	263	305	188	247
27	376	174	102	238	259	305	188	248
28	379	173	101	240	255	305	188	248
29	382	173	100	242	251	304	188	249
30	384	172	99	245	248	304	188	250
31	387		98	247	245		188	251
32	390		97	249	242		188	253
33	393		96	251	239		188	254
34	395		95	253	236		188	256
35	398		94	256	233		189	257
36	401		94	258	231		189	259
37	403		93	260	228		189	261
38	406		92	262	226		190	263
39	409		91	264	223		190	265
40	411		91	266	221		191	267

TABLE 6.--*Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 4-inch top*

4-INCH TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
5	493	400	438	516	563	452	446	500
6	416	314	322	412	468	375	359	417
7	379	271	260	352	413	335	310	369
8	360	247	222	315	379	314	280	339
9	350	233	197	290	356	303	260	318
10	345	224	179	271	340	297	245	303
11	342	215	166	258	328	295	234	291
12	342	208	156	247	320	297	226	282
13	342	203	148	238	315	300	219	275
14	344	199	141	232	311	304	214	269
15	345	195	136	226	309	310	210	264
16	348	192	131	221	308	318	206	261
17	350	190	127	217	308	314	203	258
18	352	188	123	220	309	313	200	255
19	355	186	120	222	302	311	198	253
20	358	184	118	224	296	310	196	251
21	360	182	115	226	289	309	195	250
22	363	181	113	229	284	309	194	249
23	366	180	111	231	278	308	192	249
24	369	178	109	233	273	307	192	248
25	372	177	107	235	269	307	191	248
26	374	176	106	237	264	306	190	249
27	377	175	104	239	260	306	190	249
28	380	174	103	242	256	306	189	250
29	383	174	102	244	253	305	189	250
30	385	173	100	246	249	305	189	251
31	388		99	248	246		189	252
32	391		98	250	243		189	254
33	393		97	252	240		189	255
34	396		96	254	237		189	256
35	399		95	256	234		190	258
36	401		95	258	231		190	260
37	404		94	261	229		190	262
38	406		93	263	226		191	264
39	409		92	265	224		191	266
40	412		92	267	222		192	268

TABLE 7.--*Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 6-inch top*

6-INCH TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	605	464	635	1,001	972	1,937	736	936
2	482	467	519	757	759	791	615	702
3	464	497	564	674	701	642	585	593
4	458	519	641	628	683	640	580	527
5	469	534	730	599	682	682	588	484
6	474	546	824	578	691	741	602	448
7	678	590	646	660	698	565	588	618
8	559	453	478	520	573	468	467	506
9	489	374	376	434	495	411	393	437
10	446	324	310	377	443	377	343	390
11	419	289	265	338	408	356	309	358
12	401	264	232	309	383	343	285	334
13	389	246	209	288	365	337	266	316
14	381	233	190	272	353	335	252	303
15	376	222	176	259	343	335	241	292
16	373	214	165	249	337	338	233	284
17	372	208	155	241	333	332	225	277
18	371	203	148	240	331	327	220	272
19	371	198	141	239	321	324	215	268
20	372	195	136	239	312	321	211	264
21	373	192	131	239	304	319	208	261
22	374	189	127	240	297	317	205	259
23	375	187	123	241	290	315	203	258
24	377	184	120	242	284	314	201	256
25	379	183	117	243	278	313	199	255
26	381	181	115	245	273	312	198	255
27	383	179	112	246	268	311	196	255
28	385	178	110	248	264	310	196	255
29	388	177	108	249	259	309	195	255
30	390	176	106	251	255	309	194	256
31	392		105	253	252		194	256
32	395		103	254	248		193	257
33	397		102	256	245		193	258
34	399		101	258	241		193	260
35	402		99	260	238		193	261
36	404		98	262	235		193	263
37	406		97	263	233		193	264
38	409		96	265	230		193	266
39	411		95	267	227		194	268
40	414		94	269	225		194	270

WEIGHT PER SQUARE FOOT BASAL AREA--CROWN AND TIP UNDER 3 INCHES

TABLE 8.--*Weight per square foot of basal area by d.b.h. of material less than 3 inches diameter for crowns and bole tips*

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	569	440	624	972	954	1,907	715	899
2	450	431	482	711	730	762	574	661
3	333	290	328	465	528	467	388	449
4	402	332	355	463	520	419	390	455
5	353	264	266	375	438	346	321	387
6	334	235	221	328	392	312	284	349
7	324	220	195	298	364	294	262	325
8	318	212	177	277	344	286	246	308
9	314	208	164	262	330	282	235	295
10	312	206	154	251	320	282	227	286
11	310	201	145	242	313	284	220	278
12	309	198	138	234	308	287	214	272
13	308	194	133	228	305	292	210	266
14	307	192	128	223	303	298	206	262
15	306	190	124	218	302	305	203	259
16	305	188	120	214	302	313	200	256
17	304	186	117	211	303	310	198	253
18	303	184	114	213	305	309	196	251
19	302	183	111	216	298	308	195	250
20	302	181	109	218	292	308	193	249
21	301	180	107	221	286	307	192	248
22	299	179	105	223	281	307	191	247
23	298	178	103	225	276	306	190	247
24	297	177	102	227	271	306	189	247
25	296	176	100	229	267	305	189	247
26	295	175	99	231	263	305	188	247
27	293	174	98	233	259	305	188	248
28	292	173	96	235	255	305	188	248
29	291	173	95	237	251	304	188	249
30	289	172	94	239	248	304	188	250
31	288		93	241	245		188	251
32	286		92	242	242		188	253
33	285		91	244	239		188	254
34	283		90	246	236		188	256
35	281		90	248	233		189	257
36	280		89	250	231		189	259
37	278		88	251	228		189	261
38	276		87	253	226		190	263
39	275		87	255	223		190	265
40	273		86	257	221		191	267

WOOD DENSITY

TABLE 9.--*Density of wood for selected western species. (Density values from U.S. Forest Products Laboratory (1974))*

Species	Density (lb/ft^3)
CONIFERS	
Cedar	
Western redcedar *(Thuja plicata)*	20.0
Incense cedar *(Libocedrus decurrens)*	23.1
Alaska cedar *(Chamaecyparis nootkatensis)*	27.5
Douglas-fir *(Pseudotsuga menziesii)*	
Coastal (Washington and Oregon)	30.0
Northern Rocky Mountains	30.0
Southern Rocky Mountains	28.7
Fir	
Grand fir *(Abies grandis)*	23.1
California red fir *(Abies magnifica)*	23.7
Noble fir *(Abies procera)*	24.3
Pacific silver fir *(Abies amabilis)*	26.8
White fir *(Abies concolor)*	24.3
Subalpine fir *(Abies lasiocarpa)*	20.0
Western hemlock *(Tsuga heterophylla)*	28.1
Western larch *(Larix occidentalis)*	32.4
Pine	
Lodgepole pine *(Pinus contorta)*	25.6
Ponderosa pine *(Pinus ponderosa)*	25.0
Sugar pine *(Pinus lambertiana)*	22.5
Western white pine *(Pinus monticola)*	23.7
Redwood *(Sequoia sempervirens)* Old growth	25.0
Spruce	
Engelmann spruce *(Picea engelmannii)*	21.8
White spruce *(Picea glauca)*	25.0
Sitka spruce *(Picea sitchensis)*	25.0
HARDWOODS	
Quaking aspen *(Populus tremuloides)*	23.7
Black cottonwood *(Populus trichocarpa)*	21.8

ACCURACY

Accuracy of predictions can vary considerably, depending upon species, stand conditions, and accuracy of the timber stand inventory. Sources of variation affecting predictions include equations for estimating live crown weight, dead crown weight, unmerchantable tip volume, and bark density; estimates of defect and breakage factors; and accuracy of tree inventory data. Equations for predicting live branches and foliage, which account for a major portion of the total crown weight, have standard errors of the estimate ranging from 30 to 64 percent of mean values. When weight is predicted for many trees and summed, errors for individual trees tend to balance out; thus, estimates for stand averages are expected to be more accurate than estimates for individual trees.

A test to validate predictions was conducted in three small stands dominated by a single species--ponderosa pine, Douglas-fir, and lodgepole pine. Crown weights were predicted before cutting. After cutting, the slash was intensively inventoried using the planar intersect method (Brown and Roussopoulos 1974).

For slash less than 3 inches in diameter, predicted weights were less than inventoried weights by 15, 22, and 37 percent of inventoried values. For all slash, predicted weights varied from 4 percent more, to 15 percent less than inventoried weights. Some of the discrepancies were traced to biases in the test; thus, differences between predicted weights and actual weights would be less than indicated by our test.

Considering the sources of variation inherent in predicting slash weights and a validation test, we believe that most estimates of slash weight from crowns and unmerchantable bole tips should be within 20 percent of the true mean. Occasionally, estimates can be expected to deviate from the true mean by as much as 50 percent.

FUEL APPRAISAL

Appraising potential fire behavior of fuels is often termed fuel appraisal and is the process of (1) describing fuel characteristics such as quantity and size; and (2) interpreting the fuel in terms of fire behavior; for example, rate of spread, fireline intensity, and flame length. Thus, the appraisal process attempts to answer the question: What is the expected fire behavior for different fuels, given steepness of slope and weather conditions? The question is difficult to answer, partly because the answer is made up of different elements of fire behavior (Anderson 1974): rate of spread, intensity, crowning potential, spotting potential, and duration of heat. One or more of these elements may have to be appraised when a specific fuel management situation is being evaluated.

Potential fire behavior of downed woody debris can be appraised by (1) mathematical modeling, and (2) experienced judgment. Mathematical modeling of rate of spread, fireline intensity, and flame length, for example, offers the most objective means of appraising potential fire behavior. However, this approach may not be readily available to some land managers.

Experienced judgment is an important means of appraising fuels because an experienced person can integrate many factors that elude quantification. Even when more sophisticated methods are available, judgment is still important. One way of using experienced judgment is to establish a reference (tons per acre) that can be used to compare against other fuel loadings. The reference loading should represent fuels for which a consensus of land managers experienced in control of fire can agree upon a rating. Ratings, for example, might be for low, medium, or high fire intensity potential, or either acceptable or unacceptable regarding the ability of an initial attack crew to gain control. After setting a reference loading, fuels are appraised on a relative basis. For example, for material less than 3 inches in diameter, if a loading of 10 tons per acre is established as a reference, then a loading of 20 tons per acre would exhibit approximately twice the potential fire behavior.

How Much Fuel Is Acceptable?

Fire managers commonly want to know the tonnages of fuel that are acceptable. This question is difficult to answer because fire behavior depends not only on fire potential at one location but also on other factors, such as distribution of fuels and fire behavior potential over surrounding areas that may cover one or more drainages. Acceptable fuel loading depends on resource values, management objectives for the land, pattern of land ownership, and suppression capability. In some stands, acceptable load depends on resistance of trees to crown scorch and cambium kill. Professional judgment is certainly needed to determine acceptable fuel tonnages.

Decision steps.--To decide how much fuel is acceptable requires that one must integrate many factors (fig. 3). This can be done systematically as follows:

1. Consider management objectives and values at risk. For the latter, resource values and risk of a fire during a high fire-danger period causing damage are jointly considered.

2. Appraise fuels by (a) describing fuels from inventory and prediction; and (b) interpreting fire behavior potential such as rate of spread, flame length, intensity, and scorch height.

3. Consider other fire-related factors such as fuel and fire behavior potential on adjoining areas, suppression capability, frequency and severity of historical fires, and fire's ecological role.

Acceptable fuel loadings can depend to a high degree on factors in item 3. For example, a heavier fuel loading would be acceptable on a unit surrounded by sparse fuels with little chance of ignition than on a unit surrounded by heavy fuels with a high chance of ignition.

Fuel loading standards.--No single fuel loading may be acceptable for a large administrative area. Herein lies the dilemma of setting fuel standards. Establishing standards would permit the setting of clear objectives for residue management and provide benchmarks with which to measure accomplishments. However, standards could easily circumvent professional judgment for determining the maximum acceptable level of fuel for specific sites. One approach to determining acceptable fuel levels is to develop different standards for each of the major decision circumstances encountered on a large administrative unit. To accomplish this, the factors in figure 3 should be evaluated for the different management circumstances found on a large administrative unit.

Acceptable loadings of debris also depend on requirements of other disciplines for attaining land management objectives. Thus, even if fuel standards are set, the final decision on how much downed debris is acceptable should be coordinated among land management interests.

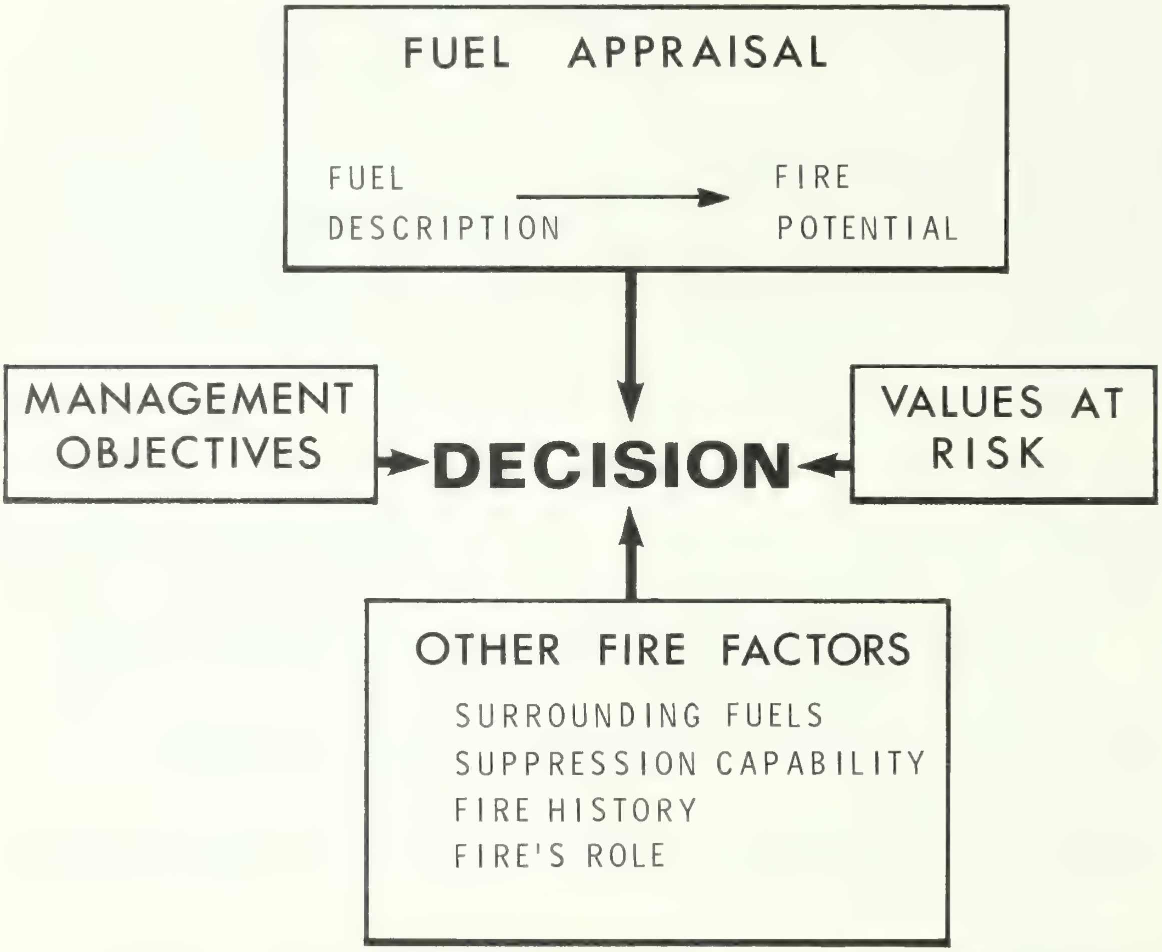


Figure 3.--Factors to consider when deciding how much fuel is acceptable.

BASIS FOR TABLES

Weights in the tables are expressed on an ovendry basis. Fractions for converting material less than 3 inches in diameter to all material and converse conversions are in appendix I.

Tables 1 through 8 show combined weights of crowns and unmerchantable tips. Relationships for estimating only crown weights for live and dead material are summarized by Brown (see footnote 1). Tables for predicting crown weights without unmerchantable tips are in appendix II. Fractions for dividing crown weights into foliage and branchwood diameter classes of 0 to 0.24 in, 0.25 to 0.99 in, 1.0 to 2.99 in, and 3.0+ in are in appendix III.

Unmerchantable tip and bole weights were computed using two methods. Brown's equations for total tree bole weight, including bark, were used for trees above the dashed lines in tables 3, 4, 7, and 8. For trees below the dashed line, weight of wood was estimated by means of unmerchantable tip volume equations developed by Faurot (see footnote 2) and wood densities from U.S. Forest Products Laboratory (1974). Bark weight was estimated from bark volumes and densities. Bark volume was calculated from ratios of bark thickness-to-stem thickness as described in appendix IV.

Faurot's equations for volume of unmerchantable tips require d.b.h. and height as independent variables. For constructing the tables, height was estimated using height-d.b.h. regressions developed by Brown (see footnote 1). Tables of tip weights and equations for tip volume and tree height are included in appendix IV.

The tables based on weight-per-square-foot of tree basal area were constructed from tables of weight per tree by d.b.h. For each d.b.h., weights per tree were divided by the basal area corresponding to that d.b.h.

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APPENDIX I

Fraction of Crowns and Tips 3 Inches and Larger

The fractions in table 10 above the dashed lines drawn at 2, 4, and 6 inches d.b.h. are based on weights that include entire boles. These fractions apply to slash from precommercial thinning and trampling where entire trees are left on the ground. Below the lines, the fractions are based on weights that include unmerchantable tips and apply to slash from harvesting operations.

TABLE 10.--*Fractions of crowns and unmerchantable bole tips that are 3 inches in diameter and larger*

D.b.h. (inches)	Species									
	PP	LP	WL	DF	GF	AF	WC	WP	WH	ES
					3-INCH TOP					
2	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
8	0.02	0	0	0	0	0	0	0	0	0
10	.04	0	0	0	0	0	0	0	0	0
12	.06	0	0.02	0	0	0	0	0	0	0
14	.09	0	.02	0	0	0	0	0	0	0
16	.11	0	.03	0.01	0	0	0	0	0	0
18	.13	0	.04	.01	0	0	0	0	0	0
20	.15	0	.04	.01	0	0	0	0	0	0
22	.17	0	.04	.01	0	0	0	0	0	0
24	.19	0	.05	.02	0	0	0	0	0	0
26	.21	0	.05	.02	0	0	0	0	0	0
28	.23	0	.05	.02	0	0	0	0	0	0
30	.25	0	.05	.02	0	0	0	0	0	0
32	.27		.05	.03	0		0	0	0	0
34	.28		.06	.03	0		0	0	0	0
36	.30		.06	.03	0		0	0	0	0
38	.32		.06	.03	0		0	0	0	0
40	.34		.06	.04	0		0	0	0	0

(con.)

TABLE 10.--*Continued*

D.b.h. (inches)	Species									
	PP	LP	WL	DF	GF	AF	WC	WP	WH	ES
					4-INCH TOP					
2	0.07	0.08	0.08	0.06	0.04	0.04	0.06	0.07	0.07	0.06
4	.24	.39	.45	.29	.25	.31	.32	.40	.33	.21
6	.18	.24	.32	.19	.15	.15	.16	.25.	.22	.15
8	.11	.13	.21	.11	.09	.08	.10	.16	.13	.09
10	.09	.08	.15	.07	.06	.05	.06	.11	.09	.05
12	.09	.05	.12	.05	.04	.03	.04	.08	.06	.04
14	.11	.03	.10	.04	.03	.02	.03	.06	.04	.03
16	.12	.02	.09	.03	.02	.01	.02	.05	.03	.02
18	.14	.02	.08	.03	.02	.01	.02	.04	.03	.01
20	.16	.01	.08	.03	.01	.01	.01	.03	.02	.01
22	.18	.01	.08	.03	.01	.01	.01	.03	.02	.01
24	.19	.01	.07	.03	.01	.01	.01	.02	.01	.01
26	.21	.01	.07	.03	.01	0	.01	.02	.01	.01
28	.23	.01	.07	.03	.01	0	.01	.02	.01	.01
30	.25	0	.07	.03	.01	0	.01	.02	.01	0
32	.27		.07	.03	.01		0	.01	.01	0
34	.29		.07	.03	.01		0	.01	.01	0
36	.30		.07	.03	0		0	.01	.01	0
38	.32		.07	.04	0		0	.01	.01	0
40	.34		.07	.04	0		0	.01	0	0
					6-INCH TOP					
2	.06	.08	.08	.06	.04	.04	.06	.07	.07	.06
4	.31	.51	.58	.38	.33	.40	.42	.53	.43	.27
6	.34	.59	.74	.46	.44	.56	.56	.69	.50	.28
8	.42	.52	.65	.46	.39	.38	.41	.57	.50	.38
10	.30	.36	.53	.33	.27	.25	.29	.45	.37	.26
12	.23	.25	.43	.24	.19	.16	.21	.36	.28	.19
14	.19	.17	.35	.18	.14	.11	.15	.28	.21	.13
16	.18	.13	.29	.14	.11	.07	.12	.23	.16	.10
18	.18	.09	.25	.11	.08	.06	.09	.19	.13	.08
20	.19	.07	.21	.09	.07	.04	.07	.15	.10	.06
22	.20	.05	.19	.07	.05	.03	.06	.13	.08	.05
24	.21	.04	.17	.06	.05	.03	.05	.11	.07	.04
26	.23	.03	.15	.06	.04	.02	.04	.09	.06	.03
28	.24	.03	.14	.05	.03	.02	.03	.08	.05	.03
30	.26	.02	.13	.05	.03	.02	.03	.07	.04	.02
32	.28		.12	.05	.03		.02	.06	.04	.02
34	.29		.11	.05	.02		.02	.06	.03	.02
36	.31		.11	.05	.02		.02	.05	.03	.01
38	.32		.10	.05	.02		.02	.04	.02	.01
40	.34		.10	.05	.02		.01	.04	.02	.01

APPENDIX II

Crown Weight Tables

TABLE 11.--*Crown weight per tree*[1]

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	1.3	1.1	1.8	3.1	3.7	8.6	2.2	2.8
2	5.7	4.3	5.5	9.4	11.3	12.4	7.3	9.3
3	13.3	9.4	10.7	18.0	21.9	18.8	14.5	18.6
4	24	17	17	29	35	28	24	30
5	39	26	24	41	51	40	35	45
6	58	37	33	55	69	55	48	61
7	80	51	42	71	90	73	63	80
8	106	67	53	89	113	94	79	101
9	137	85	64	109	139	119	97	125
10	171	106	76	130	168	149	117	150
11	210	127	89	153	200	182	139	178
12	254	150	103	178	236	221	162	208
13	302	174	117	204	275	265	188	240
14	354	200	133	233	317	314	215	275
15	411	228	149	263	364	370	244	312
16	473	258	166	295	416	433	274	352
17	540	289	183	329	471	485	307	395
18	611	322	202	375	532	542	341	439
19	688	356	221	424	581	603	378	487
20	770	392	241	476	631	667	416	538
21	856	430	261	532	683	735	456	591
22	949	469	283	591	736	805	499	648
23	1,050	510	305	654	790	879	543	708
24	1,150	553	328	720	846	957	590	771
25	1,260	597	351	790	903	1,040	639	837
26	1,370	642	375	864	962	1,120	690	907
27	1,490	690	400	941	1,020	1,210	743	980
28	1,620	739	426	1,020	1,080	1,300	799	1,060
29	1,750	789	452	1,110	1,150	1,390	857	1,140
30	1,880	841	479	1,200	1,210	1,490	917	1,220
31	2,030		506	1,290	1,280		980	1,310
32	2,170		535	1,390	1,340		1,040	1,410
33	2,330		564	1,490	1,410		1,110	1,500
34	2,490		593	1,590	1,480		1,180	1,610
35	2,660		624	1,700	1,550		1,260	1,720
36	2,830		655	1,820	1,620		1,330	1,830
37	3,010		686	1,930	1,700		1,410	1,950
38	3,190		719	2,060	1,770		1,490	2,070
39	3,390		752	2,190	1,850		1,570	2,200
40	3,580		786	2,320	1,920		1,660	2,330

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[1] Numbers within the lined space are within limits of data sampled.

TABLE 12.--*Crown weight per square foot of basal area*

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
					Pounds			
1	244	207	333	573	680	1,577	411	519
2	260	196	254	432	520	568	333	425
3	271	192	218	367	446	382	296	379
4	280	190	195	328	402	319	272	349
5	287	189	180	302	372	291	256	328
6	293	190	168	282	351	278	244	313
7	299	191	159	267	335	271	234	300
8	304	192	151	256	324	269	226	290
9	309	193	145	246	315	270	220	282
10	314	195	140	238	308	272	215	275
11	319	193	135	232	303	276	211	270
12	323	191	131	226	300	281	207	265
13	327	189	127	222	298	287	204	261
14	331	187	124	218	297	294	201	257
15	335	186	121	214	297	302	198	255
16	339	185	119	211	298	310	196	252
17	342	183	116	209	299	308	195	250
18	346	182	114	212	301	307	193	249
19	349	181	112	215	295	306	192	247
20	353	180	110	218	289	306	191	247
21	356	179	109	221	284	305	190	246
22	359	178	107	224	279	305	189	245
23	363	177	106	227	274	305	188	245
24	366	176	104	229	269	305	188	245
25	369	175	103	232	265	304	187	246
26	372	174	102	234	261	304	187	246
27	375	173	101	237	257	304	187	247
28	378	173	100	239	253	304	187	247
29	381	172	98	241	250	304	187	248
30	384	171	98	244	247	303	187	249
31	386		97	246	244		187	251
32	389		96	248	241		187	252
33	392		95	250	238		187	253
34	395		94	253	235		188	255
35	397		93	255	232		188	257
36	400		93	257	230		188	259
37	403		92	259	227		189	261
38	405		91	261	225		189	263
39	408		91	263	223		190	265
40	411		90	266	220		190	267

APPENDIX III

Crown Component Fractions

TABLE 13.--*Fraction of crown (live and dead branchwood and foliage) comprised of foliage and branchwood by size class*

	Species									
D.b.h. (inches)	PP	WL	DF	GF	AF	ES	LP	WP	WC	WH
					FOLIAGE					
0- 0.9	0.57	0.40	0.52	0.62	0.62	0.62	0.52	0.52	0.62	0.62
1- 2.9	.49	.32	.46	.59	.55	.55	.46	.51	.58	.51
3- 4.9	.44	.29	.43	.54	.49	.50	.41	.47	.55	.47
5- 6.9	.39	.27	.41	.50	.45	.47	.37	.43	.51	.43
7-10.9	.33	.23	.37	.44	.37	.42	.32	.38	.46	.38
11-14.9	.27	.20	.32	.37	.29	.36	.28	.32	.40	.33
15-18.9	.21	.17	.28	.30	.22	.31	.24	.27	.35	.28
19-22.9	.17	.14	.25	.27	.19	.25	.20	.23	.30	.23
23-26.9	.14	.12	.22	.25	.16	.21	.16	.20	.26	.20
27-30.9	.11	.10	.20	.23	.14	.18	.13	.17	.22	.17
31-34.9	.09	.08	.18	.22		.15		.14	.19	.14
35-38.9	.07	.07	.16	.20		.12		.12	.16	.12
					BRANCHWOOD 0 to 0.25 INCH					
0- 0.9	.14	.42	.27	.26	.26	.26	.27	.27	.26	.26
1- 2.9	.08	.37	.24	.23	.26	.26	.29	.26	.14	.26
3- 4.9	.06	.35	.23	.21	.25	.26	.29	.25	.13	.25
5- 6.9	.05	.33	.21	.20	.24	.25	.28	.24	.12	.23
7-10.9	.04	.30	.20	.18	.22	.23	.26	.23	.11	.20
11-14.9	.03	.27	.17	.15	.20	.22	.23	.22	.10	.17
15-18.9	.02	.24	.16	.12	.19	.20	.22	.21	.08	.14
19-22.9	.01	.21	.14	.10	.17	.18	.21	.21	.07	.12
23-26.9	.01	.18	.13	.09	.15	.17	.20	.20	.06	.10
27-30.9	.01	.16	.12	.08	.13	.15	.19	.19	.05	.08
31-34.9	.01	.14	.11	.07		.14		.18	.05	.07
35-38.9	.01	.13	.10	.07		.13		.17	.04	.05

(con.)

TABLE 13.--*Continued*

	Species									
D.b.h. (inches)	PP	WL	DF	GF	AF	ES	LP	WP	WC	WH
BRANCHWOOD 0.25 to 1 INCH										
0- 0.9	0.29	0.18	0.21	0.12	0.12	0.12	0.21	0.21	0.12	0.12
1- 2.9	.36	.31	.30	.19	.19	.19	.25	.23	.28	.23
3- 4.9	.37	.32	.31	.20	.24	.22	.29	.26	.29	.25
5- 6.9	.38	.33	.32	.23	.27	.23	.32	.28	.30	.25
7-10.9	.38	.33	.33	.27	.34	.25	.34	.29	.30	.26
11-14.9	.36	.33	.33	.31	.41	.27	.29	.30	.29	.27
15-18.9	.34	.33	.31	.34	.47	.28	.26	.31	.27	.27
19-22.9	.31	.33	.28	.32	.49	.29	.25	.31	.25	.26
23-26.9	.27	.32	.24	.28	.50	.30	.25	.31	.23	.25
27-30.9	.23	.31	.20	.25	.51	.29	.25	.31	.21	.24
31-34.9	.18	.30	.17	.21		.29		.32	.18	.23
35-38.9	.13	.28	.13	.17		.28		.31	.16	.22
BRANCHWOOD 1 to 3 INCHES										
0- 0.9	0	0	0	0	0	0	0	0	0	0
1- 2.9	.07	0	0	0	0	0	0	0	0	0
3- 4.9	.13	.04	.03	.03	.02	.02	.01	.02	.03	.03
5- 6.9	.18	.07	.06	.07	.04	.05	.03	.05	.07	.09
7-10.9	.22	.14	.10	.11	.07	.10	.08	.10	.13	.16
11-14.9	.27	.18	.18	.17	.10	.15	.20	.16	.21	.23
15-18.9	.31	.23	.24	.24	.12	.21	.28	.21	.30	.31
19-22.9	.35	.28	.32	.31	.15	.28	.34	.25	.38	.39
23-26.9	.39	.33	.39	.38	.19	.32	.39	.29	.45	.45
27-30.9	.42	.38	.46	.44	.22	.38	.43	.33	.52	.51
31-34.9	.45	.42	.51	.50		.42		.36	.58	.56
35-38.9	.48	.46	.58	.56		.47		.39	.64	.61
BRANCHWOOD 3+ INCHES										
1- 2.9	0	0	0	0	0	0	0	0	0	0
3- 4.9	0	0	0	0	0	0	0	0	0	0
5- 6.9	0	0	0	0	0	0	0	0	0	0
7-10.9	.03	0	0	0	0	0	0	0	0	0
11-14.9	.07	.02	0	0	0	0	0	0	0	0
15-18.9	.12	.03	.01	0	0	0	0	0	0	0
19-22.9	.16	.04	.01	0	0	0	0	0	0	0
23-26.9	.19	.05	.02	0	0	0	0	0	0	0
27-30.9	.23	.05	.02	0	0	0	0	0	0	0
31-34.9	.27	.06	.03	0		0		0	0	0
35-38.9	.31	.06	.03	0		0		0	0	0

APPENDIX IV

Unmerchantable Tip Weights

Weights of unmerchantable bole tips (table 14) were determined by adding together separate estimates of wood and bark. Wood weight was determined using Faurot's (see footnote 2) equations to estimate volume and wood densities from table 9 to convert volume to weight.

Faurot's equations were developed for lodgepole pine, ponderosa pine, western larch, and Douglas-fir. Comparisons of volumes among species showed that differences were small and that volume estimates for Douglas-fir were intermediate among the four species studied. On this basis, Douglas-fir volume equations were chosen to represent species not included in Faurot's work.

Solution of Faurot's equations required an estimate of height, which was provided by the equations in table 15. To avoid unreasonable extension of Faurot's equations, tip weights for trees 24 inches d.b.h. or larger are assumed to be the same.

TABLE 14.--*Weight of unmerchantable bole tips including wood and bark*

D.b.h. (inches)	Species									
	PP	LP	WL	DF	GF	AF	WC	WP	WH	ES
3-INCH TIP										
4	10.7	12.4	18.1	12.6	11.0	8.7	8.2	11.0	12.6	9.5
6	8.0	8.8	13.1	9.6	8.7	6.7	6.3	8.7	9.8	7.4
8	6.8	7.0	10.9	8.1	7.6	5.7	5.4	7.7	8.6	6.3
10	6.0	6.0	9.7	7.3	7.1	5.1	4.9	7.1	7.8	5.8
12	5.5	5.2	9.0	6.8	6.7	4.8	4.6	6.7	7.4	5.4
14	5.2	4.7	8.5	6.4	6.5	4.5	4.4	6.4	7.0	5.1
16	4.9	4.3	8.1	6.1	6.4	4.3	4.2	6.3	6.8	4.9
18	4.7	3.9	7.9	5.9	6.3	4.1	4.1	6.1	6.6	4.8
20	4.6	3.7	7.7	5.8	6.3	4.0	4.1	6.1	6.5	4.7
22	4.4	3.4	7.5	5.7	6.2	3.9	4.0	6.0	6.4	4.6
24	4.3	3.2	7.4	5.6	6.3	3.9	4.0	6.0	6.4	4.5
4-INCH TIP										
4	34.2	35.2	56.9	37.9	33.0	26.4	24.7	33.0	37.7	28.6
6	24.1	24.4	38.4	27.2	24.5	19.0	17.8	24.7	27.8	20.9
8	19.3	19.1	30.5	22.1	20.6	15.5	14.6	20.7	23.1	17.3
10	16.5	15.9	26.1	19.2	18.4	13.5	12.8	18.4	20.4	15.1
12	14.7	13.8	23.4	17.3	17.0	12.2	11.7	16.9	18.6	13.7
14	13.3	12.2	21.6	16.0	16.1	11.2	10.9	15.9	17.4	12.7
16	12.3	11.0	20.2	15.0	15.4	10.5	10.3	15.1	16.4	12.0
18	11.5	10.1	19.2	14.2	14.9	9.9	9.9	14.5	15.7	11.4
20	10.9	9.3	18.5	13.6	14.5	9.5	9.5	14.0	15.2	11.0
22	10.4	8.7	17.9	13.1	14.2	9.1	9.3	13.6	14.7	10.6
24	10.0	8.1	17.4	12.7	14.0	8.8	9.1	13.3	14.3	10.3
6-INCH TIP										
6	119.0	128.5	198.6	130.6	118.3	91.3	85.5	119.6	134.6	100.4
8	88.8	91.3	143.5	98.9	92.8	69.3	65.3	93.5	104.2	77.1
10	71.9	70.5	114.2	81.1	78.5	56.9	54.2	78.7	87.0	64.0
12	61.2	57.4	96.0	69.9	69.5	49.0	47.2	69.2	76.0	55.5
14	53.8	48.3	83.8	62.1	63.4	43.5	42.4	62.6	68.3	49.6
16	48.4	41.7	75.0	56.3	58.9	39.4	38.9	57.8	62.7	45.3
18	44.2	36.7	68.4	52.0	55.5	36.3	36.3	54.0	58.4	42.0
20	40.9	32.8	63.2	48.5	52.9	33.8	34.3	51.1	54.9	39.3
22	38.3	29.6	59.1	45.7	50.8	31.8	32.6	48.7	52.2	37.2
24	36.0	27.0	55.7	43.4	49.1	30.1	31.3	46.8	49.9	35.4

BLE 15.--*Height-d.b.h. relationships for trees from a variety of site indexes and stand densities*

Species	Number of trees	Function[1]	R^2	Standard error of estimate
derosa pine	39	$h = -43.86 + 39.31\ d^{0.4040}$	0.90	12.0
tern larch	52	$h = -51.01 + 49.10\ d^{0.4065}$	.92	11.7
gepole pine	51	$h = 327.76 - 333.52\ d^{-0.1124}$	.92	5.2
tern white pine	48	$h = -37.75 + 35.98\ d^{0.4961}$	.97	7.7
nd fir	40	$h = -23.11 + 22.51\ d^{0.6166}$	.95	11.4
glas-fir	43	$h = -26.68 + 29.42\ d^{0.4697}$	.94	8.3
tern redcedar	37	$h = -15.40 + 18.80\ d^{0.6039}$	.98	6.1
tern hemlock	35	$h = -35.84 + 35.44\ d^{0.4775}$	.95	10.1
elmann spruce	34	$h = -37.84 + 34.49\ d^{0.4551}$	.93	10.8
alpine fir[2]	82	$h = -38.43 + 37.08\ d^{0.4167}$	.91	10.4

[1] d = d.b.h., inches; h = height, feet.

[2] This equation is based on data for Douglas-fir, ponderosa pine, and subalpine fir.

Bark weight was determined by multiplying ratios of bark weight-to-wood weight (R) nes estimates of wood weight. The ratios R were calculated from:

$$= \rho_b \left(\frac{\pi d_o^{2} \ell}{4} - \frac{\pi d_i^{2} \ell}{4}\right) \Big/ \rho_s \left(\frac{\pi d_i^{2} \ell}{4}\right) = \frac{\rho_b}{\rho_s}\left(\frac{d_o^{2}}{d_i^{2}} - 1\right) \qquad (4)$$

ere

ρ_b = density of bark, lb/ft^3
ρ_s = density of wood, lb/ft^3
d_o = diameter outside bark, ft
d_i = diameter inside bark, ft
ℓ = length of cylindrical tree piece, ft

Data on diameters inside and outside bark were supplied by Faurot and James ickell, USDA Forest Service, Intermountain Forest and Range Experiment Station. asurements along the entire tree length were used in the analysis. Values of R varied ostantially. Average R was greater for tip sections than entire trees; however, lues for entire trees were used to represent tips because the values seemed more reable than those from the limited data for tip sections.

Values of bark density were obtained from Smith and Kozak (1971). Values used calculate the ratios R are in table 16.

TABLE 16.--*Wood densities, bark densities, bark volume to stem volume ratios, and bark weight to stem weight ratios used in estimating weights of unmerchantable bole tips*

Species	Wood density	Bark density	Bark volume[1] / Stem volume	Bark weight[2] / Stem weight
	Lb/ft³	*Lb/ft³*		
Ponderosa pine	25.0	21.8	0.24	0.209
Lodgepole pine	25.6	26.5	.11	.114
Western white pine	23.7	26.2	.21	.232
Douglas-fir	30.0	27.4	.19	.174
Subalpine fir	20.0	[3]	[3]	.260
Grand fir	23.1	37.4	.20	.324
Western larch	32.4	24.3	.24	.180
Western hemlock	28.1	31.2	.18	.200
Western redcedar	20.0	23.1	.15	.173
Engelmann spruce	21.8	30.6	.19	.267

[1] $(d_o^2/d_i^2)-1$ from equation (4).

[2] R from equation (4).

[3] Considered same as Douglas-fir.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

- Billings, Montana
- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with the University of Nevada)

SLASH WEIGHT SUMMARY

Stand ____ Location __________

Unit ____ Date __________ Page ___ of ___

Number of trees /acre from inventory by species							Crown weight/acre (pounds) by species					
DBH												
						Total						

SUMMARY OF DEBRIS WEIGHT

(1) Cutting		(2) Trampling		(3) Breakage	
Pounds/acre	Tons/acre	Pounds/acre	Tons/acre	Pounds/acre	Tons /acre

Predicted weight, (1) + (2) + (3) Tons/acre = ________

(4) Existing downed debris, Tons/acre = ________

Total debris, (1) + (2) + (3) + (4), Tons/acre = ________

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Brown, James K., J. A. Kendall Snell, and David L. Bunnell
1977. Handbook for predicting slash weight of western conifers. USDA For. Serv. Gen. Tech. Rep. INT-37, 35 p. Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.

As an aid to managing fuel and woody debris, procedures are provided for predicting weights of slash using tables of either slash weight per tree by d.b.h., or slash weight per square foot of tree basal area by d.b.h. Slash weights include crowns (live and dead foliage and branchwood) and unmerchantable bole tips to 3-, 4-, and 6-inch diameter limits. Slash weights can be predicted for material less than and greater than 3 inches in diameter.

KEYWORDS: slash, forest fuels, tree biomass

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KEYWORDS: slash, forest fuels, tree biomass

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INTERMOUNTAIN
RANGE PLANT
NAMES AND SYMBOLS

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INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

General Technical Report INT-38
September 1977

INTERMOUNTAIN RANGE PLANT NAMES AND SYMBOLS

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This revised alphabetical list of botanical and common names of vascular plants that primarily grow on wildlands of the Intermountain region and adjacent areas has been assembled for use in quickly recording occurrence of plants in the field and for rapid machine processing of field data. Included are plants found in Utah, Nevada, southern Idaho, and Wyoming, and most Montana species.

Where there has been a recent change of a long-used name of an entry, the old name is shown in parentheses after the new name. Likewise, the old generic name of a species may be entered and followed by the now-accepted generic name in parentheses.

The list is based on phylogenetic presentations in recognized Western Floras and other publications relating to occurrence of species on wildland sites (see bibliography). Particular attention has been paid to the "Checklist of the Vascular Plants of the Intermountain Region" (Holmgren and Reveal 1966). This provides the principal base for our listings. Kelsey and Dayton's "Standardized Plant Names" (1942) as well as a revision of this work by Beetle (1970) were consulted, particularly in assembling the common names. The "Check List of Native and Naturalized Trees of the United States" (Little 1953) was referred to for names of most trees.

Many botanical names have changed since the first "Intermountain Range Plant Symbols" (1966) was published. These changes have primarily resulted from revisions of botanical names through studies by authoritative taxonomists. Benson's "The Cacti of Arizona" (1974) made it necessary to change the names of a number of cacti. Where authoritative changes have been made by botanists, they have been accepted in this plant list to make the list as current as possible. Several introduced species now widely planted, and other exotics that have become naturalized, are included

Special effort has been made to include a complete list of shrubs and trees in the Intermountain States. Subspecies and varieties have been shown where this is warranted. Many woody plants are being considered for use in artificial restoration projects for improvement of wildlife habitat, recreational areas, domestic livestock grazing, and stabilization of disturbed areas. Likewise, subspecies and occasional varietal names of grasses and forbs have been shown where current use warrants their inclusion.

Spelling of names generally follows forms in the "Government Printing Office Style Manual." Some common names, beyond those used by Kelsey and Dayton (1942), and Beetle (1970) and those used by Little (1953), are shown when they are known to be in current use. When a reference was not available for a common name, the most widely used one was accepted.

ARRANGEMENT OF PLANT NAMES

Species are grouped generally according to growth form as (1) grasses, (2) grasslike plants, (3) forbs, and (4) trees and shrubs. The cacti are included with the shrubs, and the ferns with the forbs. Within each growth form, plant names are arranged alphabetically by genera and then by species within each genus.

SYMBOLS FOR GENERA

Symbols for genera are the capitalized first five letters of the genus name, except for generic names that are duplicated. If the first five letters of two or more generic names are identical and would thus give duplicate symbols, a numeral replaces the last letter of any duplicate symbol according to alphabetic order of the whole name. For example, the genera *Anemone* and *Anemopsis* have initial *Anemo-* in common. Since *Anemone* precedes, it is coded ANEMO, and *Anemopsis* is coded ANEM2.

The 12 generic names that have fewer than five letters are spelled in full in the code. They are: *Acer*, *Beta*, *Geum*, *Iris*, *Iva*, *Nama*, *Poa*, *Rhus*, *Rosa*, *Sida*, *Sium*, and *Zea*.

SYMBOLS FOR SPECIES AND STRAINS

The symbol for each species consists of the first two letters of the generic name plus the first two letters of the species name, all in capital letters, thus: AGAR for *Agropyron arizonicum*. If the same four-letter symbol should fit two or more species, numerals are added to the duplicates; this makes a symbol of four letters plus a digit, as AGDE2. Where strain or variety is shown, the first letter of the name of the variety is added; this makes a five-letter symbol, as AGINA for *Agropyron intermedium amurense*. If there is duplication in symbols for varieties, a numeral replaces the fifth letter, as ACGL2--*Acer glabrum douglasii*.

Since capital letters have been used in all letter symbols here, we recommend that capitals be used for all symbols written on field data sheets. This practice helps prevent mistakes in interpretation, both in the field and later in the office.

Omissions and errors no doubt are present. Since a future revision is contemplated, suggestions, comments, and notes on additions and errors are welcome. They should be sent to the Director, Intermountain Forest and Range Experiment Station, 507 - 25th Street, Ogden, Utah 84401.

Alpha code	Scientific name	Common name
[illegible]	×Agrohordeum spp.	[illegible]
[illegible]	macounii	Macoun wildrye
AGROP	Agropyron spp.	Wheatgrass
AGAL	albicans	Montana wheatgrass
AGAR	arizonicum	Arizona wheatgrass
AGBA	bakeri	Baker wheatgrass
AGBR	brachyphyllum	
AGCA	caespitosum	
AGCA2	caninum	Bearded wheatgrass
AGCI	ciliatiflorum	
[illegible]	[illegible]	
AGCR	cristatum	Fairway wheatgrass
AGDA	dasystachyum	Thickspike wheatgrass
AGDE	desertorum	Crested or desert wheatgrass
AGEL	elmeri	Elmer wheatgrass
AGEL2	elongatiforme	
AGEL3	elongatum	Tall wheatgrass
AGGL2	glaucum	
AGGR	griffithsii	Griffiths wheatgrass
AGIN	intermedium intermedium	Intermediate wheatgrass
AGINA	intermedium amurense	Amur wheatgrass
AGJU	junceum	Rushleaf wheatgrass
AGKO	kosanini	
AGLA	latiglume	Subalpine wheatgrass
AGLI	littorale	
[illegible]	[illegible]	
[illegible]	[illegible]	
AGPS	pseudorepens	False quackgrass
AGPU	pungens	Stiffleaf quackgrass
AGRE	repens	Quackgrass
AGRI	riparium	Streambank wheatgrass
AGSA	saxicola	[illegible] wheatgrass
AGSA2	saundersii	Saunders wheatgrass
AGSC	scribneri	Scribner wheatgrass

Alpha code	Scientific name	Common name
[illegible]	Agropyron spp.	[illegible]
AGSE	semicostatum	[illegible] wheatgrass
AGSI	sibiricum	Siberian wheatgrass
AGSM	smithii [illegible]	Bluestem or western wheatgrass
AGSMM	smithii molle	
AGSMP	smithii palmeri	
AGSPS	spicatum spicatum	Bearded bluebunch wheatgrass
AGSPI	spicatum inerme	Beardless bluebunch wheatgrass
AGSPP	spicatum pubescens	Hairy bluebunch wheatgrass
AGSUS	subsecundum subsecundum	Bearded wheatgrass
AGSUA	subsecundum andinum	Alpine bearded wheatgrass
AGTR	trachycaulum	Slender wheatgrass
AGTR2	trichophorum	Stiffhair or Pubescent wheatgrass
AGTR3	triticeum	Annual wheatgrass
AGROS	Agrostis spp.	Bentgrass
AGAL	alba	see A. gigantea
AGBO	borealis	Arctic bentgrass
AGCA3	castellana	Castille bentgrass
AGDI	diegoensis	Thingrass
AGGI2	gigantea	Redtop
AGEX	exarata	Spike bentgrass
AGHI	hiemalis	Winter bentgrass
AGHU	humilis	Alpine bentgrass
AGID	idahoensis	Idaho redtop
AGLE	lepida	Sequoia bentgrass
AGMI	microphylla	Smallleated bentgrass
AGOR	oregonensis	Oregon bentgrass
AGPA	palustris	Creeping bentgrass
AGRO	rossae	Ross redtop
AGSC5	scabra	Rough bentgrass

GRASSES

AGROS	Agrostis spp. [illegible]	
AGSE	semiverticillata	Water bentgrass
AGST	stolonifera	Carpet bentgrass
AGTE	tenuis	Colonial bentgrass
AGTH	thurberiana	Thurber bentgrass
AGVA	variabilis	
ALOPE	Alopecurus spp.	Foxtail
ALAE	aequalis	Shortawn foxtail
ALAL	alpinus	Alpine foxtail
ALAR	arundinacea	Reed foxtail
ALCA3	carolinianus	Carolina foxtail
ALGE3	geniculatus	Water foxtail
ALPA3	pallescens	Washington foxtail
ALPR	pratensis	Meadow foxtail
ANDRO	Andropogon spp.	Bluestem
ANBA	barbinodis	Cane bluestem
ANGE	gerardi	Big bluestem
ANGL	glomeratus	Bush bluestem
ANHA	hallii	Sand bluestem
ANHI	hirtiflorus	Santa Fe bluestem
ANSA	saccharoides	Silver bluestem
ANSC	scoparius [illegible] (Schizachyrium)	Little bluestem
ARIST	Aristida spp.	Three-awn
ARAD	adscensionis	Sixweek three-awn
ARAR2	arizonica	Arizona three-awn
ARDI	divaricata	Poverty three-awn
ARFE	fendleriana	Fendler three-awn
ARGL	glauca	Blue three-awn
ARHA	hamulosa	Mesa three-awn
ARLO1	longiseta longiseta	Red three-awn
ARLOR	longiseta [illegible]	
ARLO3	longiseta robusta	
AROL	oligantha	Prairie three-awn
ARPA6	parishii	Parish three-awn
ARPUH	purpurea	Purple three-awn
ARWR	wrightii	Wright three-awn

GRASSES

AVENA	Avena spp.	Oat
AVBA	barbata	Slender oat
AVBR	[illegible]	
AVFAF	fatua fatua	Wild oat
AVFAG	fatua glabrata	
AVFI	[illegible]	
AVSA	sativa	Common oat
BECKM	Beckmannia spp.	Sloughgrass
BESY	syzigachne	American sloughgrass
BLEPH	Blepharidachne spp.	Desertgrass
BLKI	kingii	King desertgrass
BLEP3	Blepharoneuron spp.	Dropseed or Pinegrass
BLTR	tricholepis	Pine dropseed
BOUTE	Bouteloua spp.	Grama
BOAR	aristidoides	Needle grama
BOBA	barbata rothrockii	Sixweeks grama
BOCU	curtipendula	Sideoats grama
BOER	eriopoda	Black grama
BOGR	gracilis	Blue grama
BOHI	hirsuta	Hairy grama
BOSI2	simplex	Mat grama
BOTR	trifida	Red grama
BOUN	uniflora	Nealley grama
BRACH	Brachypodium spp.	False brome
BRDI	distachyon	Purple false brome
BRPH	phoenicoides	
BRPI	pinnatum	Japanese false brome
BRSY	sylvaticum	Slender false brome
BROMU	Bromus spp.	Brome
BRAR	[illegible]	Australian chess
[illegible]	[illegible]	[illegible]
BRAR	arvensis	Field brome
[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Rattlesnake brome
[illegible]	[illegible]	Mountain brome
BRCI	ciliatus	Fringed brome

BROMU	Bromus spp.	[illegible]
BRCOA	commutatus apricorum	[illegible] brome
BRER	erectus	Meadow brome
BRFI	fibrosus	
BRFR2	frondosus	Weeping brome
BRHA	haenkeanus	
BRIN	inermis	Smooth brome
BRJAJ	japonicus japonicus	Japanese chess
BRJAP	japonicus porrectus	
BRLA	lanatipes (lanceolatus)	Woolly brome
BRMA	marginatus	Big mountain brome
BRMO	mollis	Soft chess
BROR	orcuttianus	Orcutt brome
BRPA	paniculatus	
BRPO	polyanthus	Foothill brome
BRPO2	porteri	Nodding brome
BRPUP	pumpellianus pumpellianus	Pumpelly brome
BRPUT	pumpellianus tweedyi	Pumpelly tweedy brome
BRRA	racemosus	Bald brome
BRRI	richardsonii	Fringed brome
BRRIR	rigidus rigidus	Ripgut brome
BRRI	rigidus gussonei	Longarm ripgut brome
BRRI2	riparius	
BRRU	rubens	Foxtail brome
BRSC	scoparius	Broom brome
BRSE	secalinus	Chess brome
BRSI	sitchensis	Alaska brome
BRST	stamineus	Harlan brome
BRST2	sterilis	Poverty brome
BRSY2	syriacus	
BRTET	tectorum tectorum	Cheatgrass brome
BRTEG	tectorum glabratus	Cheatgrass brome
BRTO	tomentellus	Subalpine brome
BRTR	trinii	Chilean chess
BRUN	unioloides	Rescue brome
BRVU	vulgaris	Columbia brome
BRWI	willdenowii (catharticus)	Rescue grass
CALAM	Calamagrostis spp.	Reedgrass
CACA	californica	Sierra reedgrass
CACAC	canadensis canadensis	Bluejoint reedgrass
CACAM	canadensis macounii	Macoun bluejoint reedgrass
CAEP	epigeios	Chee reedgrass

CALAM	Calamagrostis spp. (con.)	
CAIN	inexpansa	Northern reedgrass
CAKO	koelerioides	Fireweed
CAMO	montanensis	Plains reedgrass
CANE	neglecta	Slimstem reedgrass
CAPU	purpurascens	Purple pinegrass
CARU	rubescens	Pinegrass
CASC	scopulorum	Jones reedgrass
CASC2	scribneri	Scribner reedgrass
CATW	tweedyi	Cascade reedgrass
CALAM2	Calamovilfa spp.	Sandreed
CAGI	gigantea	Big sandreed
CALO	longifolia	Prairie sandreed
CATAB	Catabrosa spp.	Brookgrass
CAAQ	aquatica	Brookgrass
CENCH	Cenchrus spp.	Sandbur
CEPA	pauciflorus	Field sandbur
CHLOR	Chloris spp.	Windmillgrass
CHVE	verticillate	Tumble windmillgrass
CHVI2	virgata	Feather windmillgrass
CINNA	Cinna spp.	Woodseed
CILA	latifolia	Drooping woodseed
CYNOD	Cynodon spp.	Bermuda grass
CYDA	dactylon	Bermuda grass
CYNOS	Cynosurus spp.	Dogtail
CYCR	cristata	Crested dogtail
DACTY	Dactylis spp.	Orchardgrass
DAGL	glomerata	Orchardgrass
DANTH	Danthonia spp.	Danthonia
DACAC	californica californica	California danthonia
DACAA	californica americana	Hairy california danthonia
DAIN	intermedia	Timber danthonia
DAPA2	parryi	Parry danthonia
DASP	spicata	Poverty danthonia
DAUN	unispicata	One-spike danthonia

GRASSES

DESCH	Deschampsia spp.	Hair grass
DEAT	atropurpurea	Mountain hair grass
DECA	caespitosa	Tufted hair grass
DEDA	danthonioides	Annual hair grass
DEEL	elongata	Slender hair-grass
DIGIT	Digitaria spp.	Crabgrass or Fingergrass
DIIS	ischaemum	Smooth crabgrass
DISA	sanguinalis	Hairy crabgrass
DISTI	Distichlis spp.	Saltgrass
DIDE	dentata	Little saltgrass
DISPD	spicata divaricata	Seashore saltgrass
DISPS	spicata stricta	Inland saltgrass
ECHI3	Echinochloa	Cockspur Barnyardgrass
ECCRC	crusgalli crusgalli	Barnyard grass
ECCRM	crusgalli mitis	Beardless barnyardgrass
ECCRZ	crusgalli zelayensis	Alkali barnyardgrass
ELEUS	Eleusine spp.	Goosegrass
ELIN	indica	Goosegrass
ELYMU	Elymus spp	Wildrye
ELAFA	affinis agoeligmoides	
ELAMA	ambiguus salmonis	Colorado wildrye
ELAMS	ambiguus strigosus	Hairyscale Colorado wildrye
ELAN2	angustus	Alti wildrye
ELAR	arenicola	Sand wildrye
ELAR2	aristatus	Purple wildrye
ELCA	canadensis	Canada wildrye
ELCH	chinensis	Chinese wildrye
ELCI	cinereus	Great Basin wildrye
ELCO	condensatus	Giant wildrye
ELDA	dahuricus	Dahurian wildrye
ELFL	flavescens	Yellow wildrye
ELGI	giganteus	Mammoth

GRASSES

ELYMU	Elymus spp. (con.)	
ELGLG	glaucus glaucus	Blue wildrye
ELGLJ	glaucus jepsonii	Jepson wildrye
ELJUJ	junceus	Russian wildrye
ELJUV	junceus vinall	
ELMO2	mollis	Common dune wildrye
ELSA2	sabulosus	Sabulosa wildrye
ELSA	salina	Salina wildrye
ELTR	triticoides	Creeping wildrye
ELPU3	pubescens	Hairyleaf creeping wildrye
ELSI3	simplex	Low creeping wildrye
ELVI	virginicus	Virginia wildrye
ENNEA	Enneapogon spp. (Pappophorum)	Spike pappusgrass
ENDE	desvauxii	Spike pappusgrass
ERAGR	Eragrostis spp	Lovegrass
ERAL3	alba	Lovegrass
ERBA	barrelieri	Mediterranean lovegrass
ERCI2	cilianensis	Stinkgrass
ERCU	curvula	Weeping lovegrass
ERDI	diffusa	Spreading lovegrass
ERHY	hypnoides	Teal lovegrass
ERLU	lutescens	Sixweeks lovegrass
ERME	megastachya	
ERNE	neomexicana	New Mexico lovegrass
EROR	orcuttiana	Orcutt lovegrass
EROX	oxylepis	
ERPE3	pectinacea	Carolina lovegrass
ERPI2	pilosa	Indian lovegrass
ERTR	trichodes	Sand lovegrass
FESTU	Festuca spp.	Fescue
FEAM	ampla	
FEAR	arida	Desert fescue
FEAR2	arizonica	Arizona fescue
FEAR3	arundinacea	Reed fescue, Alta fescue

GRASSES

FESTU	Festuca spp.	Fescue
FEAR	arizonica	Arizona fescue
FECA	californica	California fescue
[illegible]	[illegible]	
FEID	idahoensis	Idaho fescue
FEKR	[illegible]	
FEMA	[illegible]	[illegible] fescue
FEME	megalura	Foxtail fescue
FEMY	myuros	Rattail fescue
FEOC	occidentalis	Western fescue
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	Alpine fescue
	[illegible]	
[illegible]	[illegible]	Hard sheep fescue
	[illegible]	
[illegible]	[illegible]	[illegible] sheep fescue
	[illegible]	
FEPA	pacifica	Pacific fescue
[illegible]	[illegible]	[illegible] fescue
[illegible]	rubra rubra	Red fescue
[illegible]	rubra	[illegible] red fescue
	lanuginosa	
FESC	scabrella	Rough fescue
[illegible]	[illegible]	Ravine fescue
FESI	[illegible]	
FESU	[illegible]	Bearded fescue
FETH	thurberi	Thurber fescue
FEVI	viridula	Greenleaf fescue
GLYCE	Glyceria spp.	Mannagrass
GLBO	borealis	Northern mannagrass
GLDE	declinata	
GLEL	elata	Tall mannagrass
GLGR	grandis	American mannagrass
GLOC	occidentalis	Northwestern mannagrass
GLST	striata	Fowl mannagrass
HELIC	[illegible]	
	[illegible]	Alpine oat
HEMO	mortonianum	Morton alpine oat
HESP2	Hesperochloa	
	spp.	Spiketescue
HEKI	kingii	Spiketescue
HETE2	Heteropogon	
	spp.	Tanglehead
HECO	contortus	Tanglehead
HIER1	Hierochloe spp.	Sweetgrass
HIOD	odorata	Sweetgrass

GRASSES

HILAR	Hilaria spp.	Galleta
HIBE	belangeri	Curlymesquite
HIJA	jamesii	Galleta
HIRI	rigida	Big galleta
HOLCU	Holcus spp.	Velvetgrass
HOLA	lanatus	Common velvetgrass
HORDE	Hordeum spp.	Barley
HOBR	brachyantherum	Meadow barley
HOBU	bulbosum	Bulbous barley
HOHY	hystrix	Mediterranean barley
HOJU	jubatum	
	jubatum	Foxtail barley
HOJUR	jubatum caespitosum	Bobtail barley
HOLE	leporinum	Rabbit barley
HOPU2	pusillum pusillum	Little barley
HOPUP	pusillum pubens	
HOST	stebbinsii	Stebbins barley
HOVUVU	vulgare vulgare	Beardless barley
HOVUT	vulgare trifurcatum	
IMPER	Imperata spp.	Satintail
IMBR	brevifolia	California satintail
KOELE	Koeleria spp.	Koeleria
KOCR	cristata	Prairie junegrass
KOVA	vallesiana	
LEERS	Leersia spp.	Cutgrass
LEOR	oryzoides	Rice cutgrass
LEPTO	Leptochloa spp.	Sprangletop
LEFA	fascicularis	Bearded sprangletop
LEFI	filiformis	Red sprangletop
LEUN	uninervia	Mexican sprangletop
LOLIU	Lolium spp.	Ryegrass
LOMU	multiflorum	Italian ryegrass
LOPE	perenne	Perennial ryegrass
LORE	remotum	Hardy ryegrass
LORI	rigidum	Swiss ryegrass
LOTE	temulentum	Darnel ryegrass

LYCUR	Lycurus spp	Wolftail
LYPH	phleoides	Wolftail
MELIC	Melica spp	Melics, oniongrass
MEBU	bulbosa	Oniongrass
MECI	ciliata	Silky-spike melic
[illegible]	[illegible]	
MEFR	frutescens	Woody melic
MEFU	fugax	Little oniongrass
MEPO	porteri	Porter melic
MESM	smithii	Smith melic
MESP	spectabilis	Showy oniongrass
MEST	stricta	Rock melic
MESU	subulata	Alaska oniongrass
MUHLE	Muhlenbergia spp	Muhly
MUAN	andina	Foxtail muhly
MUAR	arsenei	Navajo muhly
MUAS	asperifolia	Alkali muhly
MUCU	curtifolia	Utah muhly
MUDE	depauperata	Sixweeks muhly
MUFI2	filiculmis	Slimstem muhly
MUFI	filiformis	Pullup muhly
MUJO	jonesii	Modoc muhly
MULO	longiligula	Longtongue muhly
MUME	mexicana	Wirestem muhly
MUMI2	microsperma	Little seed muhly
MUMI	minutissima	Annual muhly
MUMO2	[illegible]	Modoc muhly
MUMO	montana	Mountain muhly
MUMO2	monticola	Mesa muhly
MUMU	mundula	Johnson muhly
MUPA	pauciflora	New Mexican muhly
MUPO	polycaulis	Cliff muhly
MUPO	porteri	Bush muhly
MUPU	pungens	Sandhill muhly
MURA	racemosa	Green muhly
MURE	repens	Red muhly
MURI	richardsonis	Mat muhly
MUTH	thurberi	Thurber muhly
MUTO	torreyi	Ring muhly
MUUT	utilis	Aparejo grass
MUWO	wolfii	Wolf muhly
MUWR	wrightii	Spike muhly
MUNRO	Munroa spp	False buffalograss
MUSQ2	squarrosa	False buffalograss
ORYZO	Oryzopsis spp	Ricegrass
ORAS	asperifolia	Roughleaf ricegrass
ORBL	bloomeri	Bloomers ricegrass
OREX	exigua	Little ricegrass
ORHYH	hymenoides hymenoides	Indian ricegrass
ORHYC	hymenoides contracta	
ORYZO	Oryzopsis spp	(cont.)
ORMI	micrantha	Littleseed ricegrass
ORMI2	miliacea	Smilograss
ORPA	paradoxa	
ORSW	swallenii	
ORWE	webberi	Webber ricegrass
PANI	Panicum spp	Witchgrass
PABUB	bulbosum bulbosum	Bulb panicum
PABUM	bulbosum minus	
PACA	capillare	Common witchgrass
PADI	dichotomiflorum	Fall panicum
PAFL	flexile	
PAHA	hallii	Halls panicum
PAHI	hirticaule	Roughstalk witchgrass
PAHUH	huachucae huachucae	Huachuca panicum
PAHUF	huachucae fasciculatum	
PALE	lepidulum	
PAMI	miliaceum	Broomcorn millet
PAOB	obtusum	Vine-mesquite
PAOC	occidentale	
PAPA	pacificum	Pacific panicum
PASC	scribnerianum	Scribner panicum
PASW	swallenii	
PATE	tennesseense	Tennessee panicum
PATH	thermale	Hotsprings panicum
PAVI	virgatum	Switchgrass
PAWE	webberi	Webber ricegrass
PASPA	Paspalum spp	
PADI2	dilatatum	Dallis grass
PADI3	distichum	Knotgrass
PENNI	Pennisetum spp	
PEPU	purpureum	Napiergrass
PHALA	Phalaris spp	Canarygrass
PHAQ	aquatica	
PHAR	arundinacea	Reed canarygrass
PHCA4	caroliniana	Carolina canarygrass

PHCO2	coerulescens	Sunol canarygrass
PHLEU	Phleum spp.	Timothy
PHAL	alpinum	Alpine timothy
PHBO	boehmeri	
PHIR	iranicum	
PHMO	montanum	
PHNO	nodosum	
PHPA3	paniculatum	British timothy
PHPH	phleoides	Dryland timothy
PHPR	pratense	Timothy
PHRAG	Phragmites spp	Reed
PHCO4	communis	Common reed
POA	Poa spp	Bluegrass
POAL	alpina	Alpine bluegrass
POAM	ampla	Big bluegrass
POAN3	annua	Annual bluegrass
POAR2	arctica	Arctic bluegrass
POAR	arida	Plains bluegrass
POBI2	bigelovii	Bigelow bluegrass
POBO	bolanderi	Bolander bluegrass
POBU	bulbosa	Bulbous bluegrass
POCA	canbyi	Canby bluegrass
POCO	compressa	Canada bluegrass
POCU2	curta	Wasatch bluegrass
POCU	cusickii	Cusick bluegrass
POEP	epilis	Skyline bluegrass
POFE	fendleriana	Mutton bluegrass
POGL2	glaucifolia	Pale leaf bluegrass
POGR	gracillima	Slender bluegrass
POIN2	incurva	
POIN	interior	Inland bluegrass
POJU	juncifolia	Alkali bluegrass
POLE	leibergii	Leiberg bluegrass
POLE2	leptocoma	Bog bluegrass
POLE3	lettermani	Letterman bluegrass
POLO	longiligula	Longtongue muttongrass
POMA	macroclada	
PONE3	nemoralis	Wood bluegrass
PONE2	nervosa	Wheeler bluegrass
PONE	nevadensis	Nevada bluegrass
POPA	palustris	Fowl bluegrass
POPA2	pattersoni	Patterson bluegrass
POPR	pratensis	Kentucky bluegrass
POPR2	pringlei	Pringle bluegrass
PORE	reflexa	Nodding bluegrass
PORH	rhizomata	Timberline bluegrass
POSC	scabrella	Pine bluegrass
POSE	secunda (sandbergii)	Sandberg bluegrass
POST	stenantha	Trinius bluegrass
POSU	suksdorfii	Suksdorfs bluegrass
POTR2	trivialis	Roughstal bluegrass
POVA	vaseychloa	Oregon bluegrass
POVI	violacea	
POLY4	Polypogon spp.	Polypogon
POIN3	interruptus	Ditch polypogon
POMO	monspeliensis	Rabbitfoot polypogon
POVI3	violacea	
PUCCI	Puccinellia spp	Alkaligrass
PUAI	airoides	Nuttall alkaligrass
PUDI	distans	Weeping alkaligrass
PUFA	fasciculata	Torrey alkaligrass
PULE	lemmoni	Lemon alkaligrass
PUPA	parishii	Parish alkaligrass
REDFI	Redfieldia spp	Blowoutgrass
REFL	flexuosa	Blowoutgrass
SCHED	Schedonnardus spp	Tumblegrass
SCPA	paniculatus	Tumblegrass
SCHIS	Schismus spp.	
SCAR	arabicus	Arabian mediterranean-grass
SCBA	barbatus	Mediterranean-grass
SCHIZ	Schizachyrium spp (Andropogon)	Little bluestem
SCSCS	scoparius scoparius	Little bluestem
SCSCN	scoparius neomexicanus	
SCHLE	Schlerochloa spp	Hardgrass
SCDU	dura	

GRASSES

SCLE2	Scleropogon spp.	Burrograss
SCBR	brevifolius	Burrograss
SCOLO	Scolochloa spp.	Rivergrass
SCFE	festucacea	Rivergrass
SECAL	Secale spp.	Rye
SEAN	anatolicum	
SECE	cereale	Winter rye
SEMO	montanum	Mountain rye
SETAR	Setaria spp.	Bristlegrass
SEGL	glauca	Yellow bristlegrass
SEGR	grisebachii	Grisebach bristlegrass
SEMA	macrostachya	Plains bristlegrass
SEVE2	verticillata	Hooked bristlegrass
SEVI	viridis	Green bristlegrass
SITAN	Sitanion spp.	Squirreltail
SIHA	hanseni	Hansen squirreltail
SIHO	hordeoides	
SIHYH	hystrix hystrix	Bottlebrush squirreltail
SIHYC	hystrix californicum	
SIJU	jubatum	Big squirreltail
SILO	longifolium	Longleaf squirreltail
SORGH	Sorghastrum spp.	Indiangrass
SONU	nutans	Yellow Indiangrass
SORG2	Sorghum spp.	Sorghum
SOHA	halepense	Johnson grass
SOSU	sudanense	Sudangrass
SOVU	vulgare	Sorghum sudangrass
SPART	Spartina spp.	Cordgrass
SPGR2	gracilis	Alkali cordgrass
SPPE	pectinata	Prairie cordgrass
SPHEN	Sphenopholis spp.	Wedgescale
SPIN2	intermedia	Slender wedgescale
SPOB	obtusata	Prairie wedgescale
SPORO	Sporobolus spp.	Dropseed
SPAIA	airoides airoides	Alkali sacaton
SPAIW	airoides wrightii	Sacaton
SPAS	**asper**	**Tall dropseed**

GRASSES

SPORO	Sporobolus spp. (cont.)	
SPCO	contractus	Spike dropseed
SPCR	cryptandrus	Sand dropseed
SPFL	flexuosus	Mesa dropseed
SPGI	giganteus	Giant dropseed
SPIN3	interruptus	Black dropseed
SPNE2	nealleyi	Gyp grass
SPNE	neglectus	Puffsheath dropseed
SPPU	pulvinatus	Cushion dropseed
SPTE	texanus	Texanus dropseed
STIPA	Stipa spp.	Needlegrass
STAR	arida	Mormon needlegrass
STCA	californica	Pacific needlegrass
STCO2	columbiana	Subalpine needlegrass
STCO3	comata comata	Needle-and-thread
STCO1	comata intermedia	
STCOC	coronata coronata	Crested needlegrass
STCOD	coronata depauperata	Small crested needlegrass
STEL	elmeri	Elmer needlegrass
STLE2	lemmoni	Lemon needlegrass
STLE	lettermani	Letterman needlegrass
STNE	neomexicana	New Mexico feathergrass
STOC	occidentalis	Western needlegrass
STPI	pinetorum	Pinewoods needlegrass
STRO2	robusta	Sleepygrass
STSC	scribneri	Scribner needlegrass
STSP_	speciosa	Desert needlegrass
STTH	thurberiana	Thurber needlegrass
STVI	viridula	Green needlegrass
STWE	webberi	Webber needlegrass
STWI	williamsii	Williams needlegrass
TAENI	Taeniatherum spp.	
TACA	caput-medusae	Medusahead
TORRE	Torreyochloa spp.	Falsemanna
TOER	erecta	Spike falsemanna
TOPA	pauciflora	Weak falsemanna

TRAGU	Tragus spp.	Burgrass
TRBE	berteronianus	Spike burgrass
TRICH	Trichachne spp.	Cottontop
TRCA	californica	Arizona cottontop
TRIDE	Tridens spp.	Tridens
TREL	elongatus	Rough tridens
TRMU	muticus	Slim tridens
TRPI2	pilosus	Hairy tridens
TRPU	pulchellus	Fluffgrass
TRISE	Trisetum spp.	Trisetum
TRCA4	canescens	Tall trisetum
TRCE	cernuum	Nodding trisetum
TRMO3	montanum	Rocky Mountain trisetum
TRSP	spicatum	Spike trisetum
TRWO	wolfii	Wolfs trisetum
TRITI	Triticum spp.	Wheat
TRAE	aestivum	Wheat
TRDU3	durum	Durum wheat
VULPI	Vulpia spp. (Festuca)	Sixweeks fescue
VUOCO	octoflora octoflora	Sixweeks fescue
VUOCH	octoflora hirtella	
VUOCT	octoflora tenella	
ZEA	Zea spp.	Corn
ZEMA	mays	Maize, Indian corn

GRASSLIKE PLANTS

Alpha code	Scientific name	Common name
BULBO	Bulbostylis spp	
BUCA	capillaris	
CAREX	Carex spp	Sedge
CAAB	ablata	Serrate sedge
CAAB2	aboriginum	
CAAB3	abrupta	Abruptbeak sedge
CAAL	albo nigra	Black and white sedge
CAAL2	alma	
CAAM2	amplifolia	Bigleaf sedge
CAAN2	angustior	Narrowleaf sedge
CAAP	aperta	
CAAQ2	aquatilis	Water sedge
CAAR4	arapahoensis	Arapaho sedge
CAAR2	arcta	
CAAR3	arctogena	
CAAT	atherodes	
CAAT2	athrostachya	Slenderbeak sedge
CAAT3	atrata	Black sedge
CAAT5	atrata atrosquama	Black sedge
CAAT6	atrata chalciolepis	
CAATE	atrata erecta	
CAAT4	atrosquama	
CAAU2	aurea	Golden sedge
CABA	backii	
CABE2	bebbii	Beautiful sedge
CABE3	bella	Showy sedge
CABI	bigelovii	Bigelow sedge
CABI2	bipartita	
CABO	bolanderi	Bolander sedge
CABR2	brevior	
CABR3	brevipes	Shortstemmed sedge
CABR5	breweri	
CABR4	brunnescens	Brownish sedge
CABU3	buxbaumii	Buxbaum sedge
CACA2	californica	California sedge
CACA3	canescens	Pale sedge
CACA4	capillaris	Hairlike sedge
CACA5	capitata	
CACH	chalciolepis	
CACO2	comosa	
CACO3	concinnoides	Northwestern sedge
CACR3	crawei	
CACR2	crawfordii	Crawford sedge
CACU	cusickii	Cusick sedge
CADE	deweyana	Dewey sedge
CADI	diandra	Lesserpanicled sedge

GRASSLIKE PLANTS

Alpha code	Scientific name	Common name
[illegible]	[illegible]	
CADI3	dioica gynocrates	
CADI2	disperma	Softleaved sedge
CADO	douglasii	Douglas sedge
CADR2	drummondiana	
CAEB	ebenea	Ebony sedge
CAEG	egglestonii	Eggleston sedge
CAEL	eleocharis	Needleleaf sedge
CAEL3	elymoides	Blackroot sedge
CAEN	engelmannii	Engelmann sedge
CAEP2	epapillosa	Smoothfruit sedge
CAEU	eurycarpa	Widefruit sedge
CAEX	exserta	Shorthair sedge
CAEX2	exsiccata	Columbia sedge
CAFE	festivella	Ovalhead sedge
CAFE2	feta	
CAFI	filifolia	Threadleaf sedge
CAFI2	fissuricola	
CAFL2	flava	Yellow sedge
CAFO	foenea	Silvertop sedge
CAFOV	foetida vernacula	
CAGA	garberi	Garber sedge
CAGE2	geophila	Dryland sedge
CAGE	geyeri	Elk sedge
CAGY	gynocrates	Bog sedge
CAHA	hallii	Hall sedge
CAHA2	hassei	
CAHA3	haydeniana	Cloud sedge
CAHE3	heliophila	Sun sedge
CAHE4	helleri	
CAHE5	hepburnii	Hepburn sedge
CAHE6	heteroneura	
CAHO2	hoodii	Hood sedge
CAHO5	hookerana	Hooker sedge
CAHY	hystricina	Bottlebrush sedge
CAID	idahoa	
CAIL	illota	Sheep sedge
CAIN3	integra	Smoothbeak sedge
CAIN4	interior	Inland sedge
CAJE	jepsonii	
CAJO	jonesii	Jones sedge
CAKE2	kelloggii	Kellogg sedge
CALA	laeviculmis	Smoothstem sedge
CALA2	lanuginosa	Woolly sedge
CALA3	lasiocarpa	Woolfruit sedge
CALE7	lenticularis	
CALE4	leporinella	Sierrahare sedge
CALE5	leptalea	Bristlestalked sedge
CALE6	leptopoda	Shortscale sedge
CALI	limnophila	

CAREX	Carex spp. con.	
CALI3	limosa	Mud sedge
CALI2	livida	Livid sedge
CALU	luzulaefolia	
CALU2	luzulina	Wingseed sedge
CAMA	mariposana	
CAME	media	
CAMI	microptera	Smallwing sedge
CAMI3	misandra	Shortleafed sedge
CAMI4	miserabilis	
CAMO3	montanensis	Montana sedge
CAMU	multicaulis	
CAMU2	multicostata	Manyrib sedge
CAMU3	muricata	
CANA	nardina	
CANE2	nebraskensis	Nebraska sedge
CANE3	nelsonii	
CANE4	nervina	
CANE5	neurophora	Alpinenerved sedge
CANI2	nigricans	Black alpine sedge
CANO2	norvegica	
CANO	nova	
CAOB	obtusata	Obtuse sedge
CAOC2	occidentalis	Western sedge
CAOEV	oederi viridula	
CAPA5	pachystachya	Chamisso sedge
CAPA7	parryana	
CAPA6	paupercula	
CAPA8	pausonis	
CAPE2	pelocarpa	
CAPE3	perglobosa	Mt. Baldy sedge
CAPE	petasata	Liddon sedge
CAPH	phaeocephala	Dunhead sedge
CAPH2	physocarpa	
CAPI	pityophila	
CAPL	platylepis	
CAPO	podocarpa	Shortstalk sedge
CAPR2	praeceptorum	
CAPP	praegracilis	Silver sedge
CAPR3	praticola	Meadow sedge
CAPR4	preslii	Presl sedge
CAPR5	proposita	
CAPS	pseudoscirpoidea	
CAPY	pyrenaica	Pyrenean sedge
CARA2	raynoldsii	Raynolds sedge
CARE	retrorsa	Knotsheath sedge
CARO	rossii	Ross sedge
CARO4	rostrata	Beaked sedge
CARU3	rupestris	Rock sedge
CARU2	rusbyi	Rusby sedge
CASA2	saximontana	Rocky Mountain sedge
CASA3	saxatilis	
CASAC	scirpoidea curatorum	

CAREX	Carex spp (con.)	
CASAP	scirpoidea pseudoscirpoidea	
CASAS	scirpoidea stenochlaena	
CASC3	scopulorum	Cliff sedge
CASH	sheldonii	Sheldon sedge
CASI3	siccata	Silvertop sedge
CASI	simulata	Analogue sedge
CASI2	sitchensis	Sitka sedge
CASP	specifica	
CASP2	spectabilis	Showy sedge
CAST4	stenophylla	
CAST2	stipata	Prickly sedge
CAST3	straminiformis	Shasta sedge
CASU3	subfusca	
CASU2	subnigricans	
CATE	teneraeformis	Sierraslim sedge
CATO	tolmiei	Tolmie sedge
CATR2	tracyi	Tracy sedge
CAVA	vallicola	Valley sedge
CAVE2	vernacula	Alpine blackheaded sedge
CAVE3	vesicaria	Blister sedge
CAVI	viridula	Green sedge
CAVU	vulpinoidea	Fox sedge
CAXE	xerantica	
CLADI	Cladium spp.	Saw-grass
CLMAC	mariscus var. californicum	
CYPER	Cyperus spp	Flat-sedge
CYAC2	acuminatus	Taperleaf flat-sedge
CYAR	aristatus	Bearded flat-sedge
CYER	erythrorhizos	Redroot flat-sedge
CYES	esculentus	Chufa flat-sedge
CYFE2	fendlerianus	Fendler flat-sedge
CYNI2	niger	Blackhead flat-sedge
ELEOC	Eleocharis spp.	Spikerush
ELAC	acicularis	Needle spikerush
ELAC2	acuminata	
ELAT	atropurpurea	
ELBE	bella	
ELBO	bolanderi	
ELEN	engelmannii	Engelmann spikerush
ELFL2	flaccida	
ELMA	macrostachya	Common spikerush
ELMO	montevidensis	

GRASSLIKE PLANTS

ELEOC	Eleocharis spp.	Spikerush
ELPA	palustris	
ELPA2	parvula	Dwarf spikerush
ELPA3	pauciflora	Fewflowered spikerush
ELRA	radicans	
ELRO	rostellata	Beaked spikerush
ERIOP	Eriophorum spp.	Cotton sedge
ERAL4	altaicum	
ERAN2	angustifolium	Narrowleaf cotton-sedge
ERCH5	chamissonis	Chamiss cotton sedge
ERGR	gracile	Slender cotton-sedge
FIMBR	Fimbristylis spp.	
FISP	spadicea	
HEMIC	Hemicarpha spp.	
HEMI2	micrantha	
JUNCU	Juncus spp.	Rush, wiregrass
JUAB	abjectus	
JUAC	acuminatus	Tapertip rush
JUAC2	acutus	
JUAL	albescens	
JUAL2	alpinus	Alpine rush
JUAR	articulatus	
JUBA2	badius	
JUBA	balticus	Baltic rush
JUBR	bryoides	
JUBU	bufonius	Toad rush
JUCA	castaneus	
JUCH	chlorocephalus	
JUCO	columbianus	Columbian rush
JUCO2	confusus	Colorado rush
JUCO3	cooperi	Cooper rush
JUDR	drummondii	Drummond rush
JUEF	effusus	Common rush
JUEN	ensifolius	Swordleaf rush
JUFI	filiformis	Thread rush
JUGE	gerardii	Saltmeadow rush
JUHA	hallii	Halls rush
JUHE	hemiendytus	
JUIN	interior	Inland rush
JUJO	jonesii	
JUKE	kelloggii	
JULO	longistylis	Longstyle rush
JUME	mertensianus	Mertens rush
JUME2	mexicanus	
JUNE	nevadensis	Nevada rush
JUNO	nodosus	Jointed rush

GRASSLIKE PLANTS

JUNCU	Juncus spp. (con.)	
JUOR	orthophyllus	Straightleaf rush
JUPA	parryi	Parry rush
JURE	regelii	Regel rush
JUSA	saximontanus	Rocky Mountain rush
JUSP	sphaerocarpus	
JUTE	tenuis	Poverty rush
JUTO	torreyi	Torrey rush
JUTR	tracyi	Tracy rush
JUTW	tweedyi	
JUUN	uncialis	
JUVA	vaseyi	Vasey rush
JUXI	xiphioides	
KOBRE	Kobresia spp.	Kobresia
KOBE	bellardii	
LUZUL	Luzula spp.	Woodrush
LUDI	divaricata	Forked woodrush
LUGL	glabrata	Smooth woodrush
LUIN	intermedia	Hairy woodrush
LUOR	orestera	
LUPA	parviflora	Millet woodrush
LUSP2	spicata	Spike woodrush
LUSU2	subcongesta	Donner woodrush
LUWA	wahlenbergii	Wahlenberg woodrush
SCHOE	Schoenus spp.	
SCNI	nigricans	
SCIRP	Scirpus spp.	Bulrush
SCAC	acutus	Tule bulrush
SCAM	americanus	American bulrush
SCAT	atrovirens	Green bulrush
SCCA	caespitosus	Deerhair bulrush
SCCR	criniger	
SCFL	fluviatilis	River bulrush
SCMI	microcarpus	Panicled bulrush
SCNE	nevadensis	Nevada bulrush
SCOL	olneyi	Olney bulrush
SCPA3	pallidus	
SCPA4	paludosus	Alkali bulrush
SCRU	rubrotinctus	Redstem bulrush
SCSU	supinus	Hall bulrush
SCVA	validus	Softstem bulrush
SPARG	Sparganium spp.	Burreed
SPAN	angustifolium	Narrowleaf burreed
SPEU	eurycarpum	Giant burreed
SPMI	minimum	Least burreed
SPMU2	multipedunculatum	

ABCR	crux maltae	
ABCY	cycloptera	
ABEL	elliptica	Pink sandverbena
ABFR	fragrans	Snowball sandverbena
ABLA2	latifolia	Yellow sand-verbena
ABME	mellifera	
ABMI	micranthus	Sandpuffs
ABNA	nana	Dwarf sandverbena
ABOR	orbiculata	
ABPO	pogonantha	Bearded sandverbena
ABPU	pumila	
ABSA	salsa	
ABTU	turbinata	Transmontane sandverbena
ABUM	umbellata	Pink sandverbena
ABVI	villosa	Desert sandverbena
ABWO	wootonii	
ACANT	Acanthochiton spp.	Hopiweed
ACWR	wrightii	Wright hopiweed
ACHIL	Achillea spp.	Yarrow
ACCH	chrysanthemum	
ACDE	dentifera	
ACMID	millefolium delwayi	
ACMIL	millefolium lanulosa	Western yarrow
ACPT	ptarmica	Sneezewort yarrow
ACHYR	Achyronychia spp.	
ACCO2	cooperi	
ACONI	Aconitum spp.	Monkshood
ACCO	columbianum	Columbia monkshood
ACTAE	Actaea spp.	Baneberry
ACRU	rubra	Red baneberry
(Actinea spp.--see Hymenoxys)		
ADENO	Adenocaulon spp.	Trail plant
ADBI	bicolor	American trail plant
ADIAN	Adiantum spp.	Maidenhair
ADCA	capilus-veneris	Southern maiden hair
ADPEA	pedatum aleuticum	

ADAN	annua	Pheasanteye adonis
ADOXA	Adoxa spp.	Muskroot
ADMO	moschatellina	Muskroot
AEGOP	Aegopodium spp.	
AEPO	podagraria	Bishop's weed
AEPOV	podagraria variegatum	Flo white
AGAST	Agastache spp.	Gianthyssop
AGCU	cusickii	Cusick gianthyssop
AGPA2	pallidiflora	Pale gianthyssop
AGURG	urticifolia glaucifolia	Nettleleaf gianthyssop
AGOSE	Agoseris spp	Agoseris
AGAU	aurantiaca	Orange agoseris
AGGL	glauca	Pale agoseris
AGGR	grandiflora	Bigflower agoseris
AGHE	heterophylla	Annual agoseris
AGRE	Retrorsa	Spearleaf agoseris
AGROS	Agrostemma spp.	Corncockle
AGGI	githago	Common corncockle
ALETE	Aletes spp.	
ALMA	macdougali	
ALISM	Alisma spp.	Waterplantain
ALGE	geyeri	Geyer waterplantain
ALTR	triviale	American waterplantain
ALLIO	Allionia spp.	Allionia
ALCH	choisyi	
ALIN	incarnata	Trailing allionia
ALLIU	Allium spp.	Wild onion
ALAA	aaseae	
ALAC	acuminatum	Tapertip onion
ALAN	anceps	Twin onion
ALAT	atrorubens	
ALBI	bigelovii	Bigelow onion
ALBI2	bisceptrum	Twincrest onion
ALBR	brandegei	Brandegee onion
ALBR2	brevistylum	Shortstyle onion
ALCA2	campanulatum	Sierra onion
ALCE	cernuum	Nodding onion
ALCY	cyrilli	
ALFI	fibrillum	Blue mountain onion
ALGE2	geyeri	Geyer onion

ALLIU	Allium spp.	Onion
ALLE	lemmonii	Lemmon onion
ALMA	macropetalum	Large flowered onion
ALMA3	macrum	Rock onion
ALMA4	madidum	Swamp onion
ALNE	nevadense	Nevada onion
ALPA	palmeri	Palmer onion
ALPA	parvum	Small onion
ALPL	platycaule	Flat-stem onion
ALPU	punctum	Punctate onion
ALRO	robinsonii	Robinson onion
ALRU	rubrum	
ALSC	schoenoprasum	Chive
ALSI	simillimum	
ALTE2	textile	Textile onion
ALTO	tolmiei	Tolmie onion
ALTR2	tribracteatum	Threebract onion
ALVA	validum	Pacific onion
ALLOT	Allotropa spp.	
ALVI	virgata	Candystick
ALTHA	Althaea spp.	Hollyhock
ALAR2	armeniaca	
ALCA4	cannabina	
ALLU	ludwigii	
ALNA	narbonensis	
ALRO	rosea	Hollyhock
ALTA	taurinensis	
ALYSS	Alyssum spp.	Alyssum
ALAL	alyssoides	Pale alyssum
ALDE	desertorum	
ALMI	minus	
ALSZ	szowitsianum	
AMARA	Amaranthus spp.	Amaranth or Pigweed
AMAL2	albus	Tumble pigweed
AMAR	arenicola	
AMCA	californicus	California amaranth
AMCR	cruentus	
AMFI	fimbriatus	
AMGR	graecizans	Tumbleweed amaranth
AMHY	hybridus	Slim amaranth
AMLE	leucocarpus	Love lies-bleeding
AMPA	palmeri	Palmer amaranth
AMPO	powellii	Powell amaranth
AMPU	pubescens	
AMRE2	retroflexus	Redroot amaranth
AMTO	torreyi	
AMWR	wrightii	Wright amaranth
AMBRO	Ambrosia spp. (Franseria)	Ragweed
AMAC	acanthicarpa	
AMAR2	artemisiifolia	[illegible]

AMBRO	Ambrosia spp.	
AMDI	discolor	Skeleton leaf bursage
AMLI	linearis	
AMPS	psilostachya	Western ragweed
AMTR	trifida	Giant ragweed
AMMAN	Ammannia spp.	Ammannia
AMCO	coccinea	Purple ammannia
AMSIN	Amsinckia spp.	Fiddleneck
AMIN	intermedia	Fireweed fiddleneck
AMLY	lycopsoides	Tarweed fiddleneck
AMME	menziesii	Menzies fiddleneck
AMRE	retrorsa	Rough fiddleneck
AMTE	tessellata	Western fiddleneck
AMVE	vernicosa	Vernal fiddleneck
AMSON	Amsonia spp.	Amsonia
AMBR	brevifolia	
AMEA	eastwoodiana	Eastwood amsonia
AMJO	jonesii	
AMTO2	tomentosa	
ANAGA	Anagallis spp.	Pimpernel
ANAR	arvensis	Scarlet pimpernel
ANAPH	Anaphalis spp.	Pearleverlasting
ANMA	margaritacea	Common pearl-everlasting
ANCHU	Anchusa spp.	Bugloss
ANAZ	azurea	Italian bugloss
ANOF	officinalis	Common bugloss
ANDRO	Androsace spp.	Rockjasmine
ANCA	carinata	
ANFI	filiformis	Slender rockjasmine
ANOC	occidentalis	Western rockjasmine
ANSE	septentrionalis	Pygmy rockjasmine
ANDR3	Androstephium spp.	Funnellily
ANBR	breviflorum	Purple funnellily
ANELS	Anelsonia spp.	Daggerpod
ANCU	curvicarpa	

ANEMO	Anemone spp.	Anemone
ANCY	cylindrica	Candle anemone
ANDR	drummondii	Drummond anemone
ANMU	multifida	Argentine anemone
ANPA	parviflora	Arctic anemone
ANPA2	patens	Spreading pasque flower
ANZE	zephyra	Narcissus anemone
ANEM2	Anemopsis spp.	Yerba mansa
ANCA2	californica	Yerba mansa
ANETH	Anethum spp	
ANGR	graveolens	Dill
ANGE1	Angelica spp.	Angelica
ANAM	ampla	Giant angelica
ANAR2	arguta	Sharptooth angelica
ANBR2	breweri	Brewer angelica
ANKI	kingii	King angelica
ANLI	lineariloba	Narrowleaf angelica
ANPI	pinnata	Small-leaf angelica
ANRO2	roseana	Rose angelica
ANWH	wheeleri	Wheeler angelica
ANISO	Anisocoma spp	
ANAC	acaulis	
ANTEN	Antennaria spp	Pussytoes
ANAL	alpina	Alpine pussytoes
ANAN	anaphaloides	Pearly pussytoes
ANAR3	arcuata	
ANAR4	argentea	
ANCO	corymbosa	Plains pussytoes
ANDI	dimorpha	Low pussytoes
ANFL	flagellaris	
ANGE2	geyeri	Pinewoods pussytoes
ANLA	lanata	Woolly pussytoes
ANLU	luzuloides	Rush pussytoes
ANNE	neglecta	Field pussytoes
ANPA3	parvifolia	Littleleaf pussytoes
ANPU	pulcherrima	Showy pussytoes
ANRA	racemosa	Raceme pussytoes
ANRO	rosea	Rose pussytoes
ANRO3	rosulata	
ANST	stenophylla	Narrowleaf pussytoes
ANUM	umbrinella	Umber pussytoes
ANTHE	Anthemis spp	Camomile, dogfennel
ANCO2	cotula	Mayweed camomile

ANTHE	Anthemis spp. (con.)	
ANTI	tinctoria	Golden camomile
ANTHE2	Anthericum spp	Anthericum
ANTO	torreyi	Torrey anthericum
ANTHY	Anthyllis spp.	Anthyllis
ANCO3	cornicina	
ANCY2	cytisoides	
ANLO	lotoides	
ANVU	vulneraria	Kidneyvetch anthyllis
ANTIR	Antirrhinum spp.	Snapdragon
ANFI	filipes	
ANKI2	kingii	King snapdragon
APARG	Apargidium spp	Apargidium
APBO	boreale	Common apargidium
APHYL	Aphyllanthes spp	
APMO	monspeliensis	
APIUM	Apium spp.	Celery
APGR	graveolens	Wild celery
APOCY	Apocynum spp	Dogbane
APAN	androsaemifolium pumilum	Spreading dogbane
APCA	cannabinum	Hemp dogbane
APME	medium	Intermediate dogbane
APSI	sibiricum	Prairie dogbane
AQUIL	Aquilegia spp	Columbine
AQBA	barnebyi	Yellow oil shale columbine
AQCH	chrysantha	Golden columbine
AQCO	coerulea	Colorado columbine
AQDE	desertorum	
AQEL	elegantula	Westernred columbine
AQFL	flavescens	Yellow columbine
AQFOF	formosa formosa	Sitka columbine
AQFOT	formosa truncata	California columbine
AQMI	micrantha	White oil shale columbine
AQSC	scopulorum	Utah columbine
AQSH	shockleyi	
ARABI	Arabis spp	Rockcress
ARCO1	cobrensis	Silver rockcress
ARDA	davidsonii	

ARABI	Arabis spp. (con.)	
ARDE	demissa	
ARDI2	divaricarpa	Spreading rockcress
ARDR2	drummondi	Drummond rockcress
ARFE4	fendleri	Fendler rockcress
ARFE	fernaldiana	
ARGL2	glabra	Towermustard rockcress
ARHI	hirsuta	Hairy rockcress
ARHO	holboellii	Holboell rockcress
ARIN	inyoensis	
ARLE	lemmoni	Lemons rockcress
ARLI	lignifera	Woody rockcress
ARLY	lyallii	Lyall rockcress
ARMI3	microphylla	Littleleaf rockcress
ARNU	nuttallii	Nuttall rockcress
ARPE	pendulina	
ARPE2	perennans	
ARPL	platysperma	Pioneer rockcress
ARPU3	puberula	Hoary rockcress
ARPU2	pulchra	Beauty rockcress
ARRE	repanda	
ARSC	chistacea	
ARSE	selbyi	
ARSH	shockleyi	
ARSP2	sparsiflora	Sicklepod rockcress
ARSU	suffrutescens	Woody rockcress
ARALI	Aralia spp.	Aralia
ARNU2	nudicaulis	Wildsarsaparilla
ARRA	racemosa	American spikenard
ARCEU	Arceuthobium spp.	Dwarfmistletoe
ARAM	americanum	American dwarfmistletoe
ARCA	campylopodum	Western dwarfmistletoe
ARCY	cyanocarpum	
ARDI3	divaricatum	
ARDO	douglasii	Douglas dwarfmistletoe
ARVA	vaginatum	
ARCTI	Arctium spp.	Burdock
ARMI2	minus	Smaller burdock
ARCTO	Arctomecon spp.	Bear poppy
ARCA2	californica	
ARHU	humilis	

ARCTO	Artomecon spp. (con.)	
ARME	merriamii	Desert bear poppy
ARENA	Arenaria spp.	Sandwort
ARAB	aberrans	
ARAC	aculeata	Prickly sandwort
ARCA3	capillaris	Fescue sandwort
ARCO2	congesta	Ballhead sandwort
AREA	eastwoodiae	
ARFE3	fendleri	Fendler sandwort
ARFI2	filiorum	
ARFR2	franklinii	Franklin sandwort
ARHO2	hookeri	Hooker sandwort
ARKI	kingii	Kings sandwort
ARLA	lanuginosa	
ARLA2	lateriflora	Bluntleaf sandwort
ARMA	macradenia	
ARNU3	nutallii	Nuttall sandwort
AROB	obtusiloba	Twinflower sandwort
ARRU	rubella	
ARSE2	serpyllifolia	Thymeleaf sandwort
ARST	stenomeres	
ARGEM	Argemone spp.	Prickly poppy
ARAR	arizonica	
ARCO3	corymbosa	
ARMU	munita (hispida)	Hedgehog prickly poppy
ARPO	polyanthemos	
ARGYT	Argythamnia spp.	Silverbush
ARNE2	neomexicana	
ARGYR	Argyrolobium spp.	
ARLI2	linnaeanum	
ARNIC	Arnica spp.	Arnica
ARAM2	amplexicaulis	Clasping arnica
ARCH	chamissonis	Chamisso arnica
ARCO	cordifolia	Heartleaf arnica
ARDI2	diversifolia	Sticky arnica
ARFU	fulgens	Orange arnica
ARLA3	latifolia	Broadleaf arnica
ARLO2	longifolia	Longleaf arnica
ARMO	mollis	Hairy arnica
ARNE3	nevadensis	Nevada arnica
ARPA3	paniculata	
ARPA4	parryi	Rayless arnica
ARRY	rydbergii	Rydberg arnica
ARSO	sororia	

ARTEM	Artemisia spp.	Sagebrush, wormwood
ARAB	absinthium	Common wormwood
ARAN	annua	Sweet wormwood
ARBI	biennis	Biennial wormwood
ARDR	dracunculus dracunculoides	Tarragon
ARLUL	ludoviciana ludoviciana	Louisiana sagebrush
ARLUA	ludoviciana ludoviciana albula	Silverking sagebrush
ARLUI	ludoviciana ludoviciana incompta	Mountain sagebrush
ARLU	ludoviciana ludoviciana latiloba	
ARLUM	ludoviciana ludoviciana mexicana	Mexican sagebrush
ARMI	michauxiana	Michaux sagebrush
ARNO	norvegica saxatilis	
ARSC	scopulorum	Alpine sagebrush
ARST2	stelleriana	Beach wormwood
ASCLE	Asclepias spp.	Milkweed
ASAS	asperula	
ASCO	cordifolia	Heartleaf milkweed
ASCR	cryptoceras	Pallid milkweed
ASCU	cutleri	
ASEN	engelmanniana	Engelmann milkweed
ASER	eriocarpa	Woollypod milkweed
ASER	erosa	Desert milkweed
ASFA	fascicularis	Mexican milkweed
ASHA	hallii	Hall milkweed
ASIN	incarnata	Swamp milkweed
ASIN	involucrata	Dwarf milkweed
ASLA	labriformis	
ASMA	macrosperma	
ASRU	rusbyi	
ASRU	ruthiae	
ASSP	speciosa	Showy milkweed
ASSU	subulata	Skeleton milkweed
ASSU	subverticillata	Horsetail milkweed
ASTU	tuberosa	Butterfly milkweed
ASPAR	Asparagus spp.	Asparagus
ASOF	officinalis	Garden asparagus
ASPER	Asperugo spp.	Catchweed, madwort
ASPR	procumbens	
ASPLE	Asplenium spp.	Spleenwort
ASAD	adiantum nigrum	
ASSE	septentrionale	Grassleaf spleenwort
ASTR	trichomanes	Maidenhair spleenwort
ASVI	viride	Green spleenwort
ASTER	Aster spp.	Aster
ASAL	alpigenus	
ASAR6	arenosus	Small flower aster
ASBR	brachyactis	
ASCA	campestris	Meadow aster
ASCHA	chilensis ascendens	Pacific aster
ASEA	eatonii	Eaton's aster
ASEN	engelmannii	Engelmann aster
ASER4	ericoides	Heath aster
ASFO	foliaceus	Alpine leafybract aster
ASFR	frondosus	Leafy aster
ASGL	glaucodes	Blueleaf aster
ASHE	hesperius	Siskiyou aster
ASIN	integrifolius	Thickstem aster
ASIN4	intricatus	
ASLAV	laevis	Smooth aster
ASOC	occidentalis	Western aster
ASPA	pansus	Manyflowered aster
ASPA2	pauciflorus	Fewhead aster
ASPE	perelegans	Nuttall aster
ASRU3	rubrotinctus	
ASSC	scopulorum	Crag aster
ASSI	sibiricus	Siberian aster
ASSP2	spinosus	Devilweed aster
ASST	stenomeres	Northwest aster
ASWA	wasatchensis	
ASTRA	Astragalus spp.	Locoweed, milkvetch, poisonweed
ASAC	acutirostris	Sharpkeeled milkvetch
ASAD	adanus	Boise milkvetch
ASAE	aequalis	Purple milkvetch
ASAL2	allochrous	Halfmoon locoweed
ASAL3	alpinus	Alpine milkvetch
ASAL4	alvordensis	Alvord milkvetch
ASAM3	amblytropis	Challis milkvetch
ASAMA	amnis-amissi	Lost river milkvetch
ASAM	amphioxys	Crescent milkvetch

ASTRA	Astragalus spp.	(con.)
ASAM2	ampullarius	Gumbo milkvetch
ASAN	andersonii	Anderson milkvetch
ASAR	aretioides	Cushion milkvetch
ASAR2	argophyllus	Silverleafed milkvetch
ASAR3	armeniacus	
ASAR4	arrectus	
ASAR5	arthuri	Waha milkvetch
ASAS2	asclepiadoides	Milkweed milkvetch
ASAT	atratus	Mourning milkvetch
ASAU2	austinae	
ASAU	australis	
ASBA	barnebyi	Barneby milkvetch
ASBE	Beckwithii	Beckwith milkvetch
ASBE2	bernardinus	San Bernardino milkvetch
ASBI	bigelovii	Bigelow milkvetch
ASBI2	bisulcatus	Twogrooved locoweed
ASBO	bodini	Bodin milkvetch
ASBO2	boeticus	
ASBR2	brandegei	Brandgee milkvetch
ASBR3	bryantii	Bryant milkvetch
ASCA2	californicus	California milkvetch
ASCA3	callithrix	Callaway milkvetch
ASCA	calycosus	Torrey milkvetch
ASCA5	camptopus	Bruneau milkvetch
ASCA6	canadensis (mortonii)	Canada milkvetch
ASCA7	canovirens	
ASCA8	caryocarpus	
ASCA9	casei	Case milkvetch
ASCA10	castanaeformis	Chestnut milkvetch
ASCE	ceramicus	Painted milkvetch
ASCH	chamaeleuce	Cicada milkvetch
ASCH2	chamaemeniscus	Groundcone cent milkvetch
ASCH3	chinensis	China milkvetch
ASCH4	chloodes	Grass milkvetch
ASCI	cibarius	Silky milkvetch
ASCI2	cicer	Chickpea milkvetch
ASCO2	coccineus	Scarlet milkvetch

ASTRA	Astragalus spp.	(con.)
ASCO3	collinus	Hill milkvetch
ASCO4	coltoni	Colton locoweed
ASCO	convallarius	Timber poisonvetch
ASCO6	cottamii	Cottam milkvetch
ASCR1	crassicarpus	Groundplum milkvetch
ASCR2	cremnophylax	Sentry milkvetch
ASCR3	cronquistii	Cronquist milkvetch
ASCU2	curvicarpus	Curvepod locoweed
ASCU3	cusickii	Cusick milkvetch
ASCY	cymboides	Canoe milkvetch
ASDE	desperatus	Rimrock milkvetch
ASDE3	deseretica	Indianola milkvetch
ASDE2	detritalis	Debris milkvetch
ASDI2	didymocarpus	Two seeded milkvetch
ASDI	diversifolius	Meadow milkvetch
ASDR	drummondii	Drummond milkvetch
ASDU	duchesnensis	Duschesne milkvetch
ASEA2	eastwoodiae	Eastwood milkvetch
ASEM	emoryanus	Emory milkvetch
ASEP	episcopus	Bishop milkvetch
ASER3	eremiticus	Hermit milkvetch
ASEU2	eucosmus	Elegant milkvetch
ASEU	eurekensis	Eureka milkvetch
ASFA2	falcatus	Sicklepod milkvetch
ASFI	filipes (stenophyllus)	Snakeriver plains milkvetch
ASFL	flavus	
ASFL2	flexuosus	Flexile milkvetch
ASFU	fucatus	Yellow milkvetch
ASGA	galegiformis	
ASGE	geyeri	Geyer milkvetch
ASGI	gibbsii	Gibbs milkvetch
ASGL2	globiceps	
ASHA2	hamiltonii	Hamilton milkvetch
ASHA3	hamosus	
ASHA4	harrisonii	Harrison milkvetch
ASHO	hornii	Horn locoweed
ASHO2	howellii	Howell milkvetch

ASTRA	Astragalus spp.	(con.)
ASHU	humistratus	Groundcover milkvetch
ASIN5	inflexus	Bent milkvetch
ASIN6	inversus	Lavabeds milkvetch
ASIN7	inyoensis	Inyo milkvetch
ASIO	iodanthus	Humboldt river milkvetch
ASIO2	iodopetalus	Violet milkvetch
ASIS	iselyi	Isely milkvetch
ASJE	jejunus	Starveling milkvetch
ASKE	kentrophyta	
ASLA5	lancearius	Lancer milkvetch
ASLA4	layneae	Layne milkvetch
ASLE	lemmonii	Lemmon milkvetch
ASLE2	lentiginosus	Specklepod locoweed
ASLI	limnocharis	Cedarbreaks milkvetch
ASLO2	loanus	Loa milkvetch
ASLO	lonchocarpus	Rushy milkvetch
ASLU	lutosus	Dragon milkvetch
ASLY	lyallii	Lyall milkvetch
ASMA2	malacus	Shaggy milkvetch
ASMA4	malacoides	Kaiparowits milkvetch
ASMA3	marianus	Sevier milkvetch
ASME	megacarpus	Great bladdery milkvetch
ASME2	mexicanus	
ASMI	minthorniae	Minthorn milkvetch
ASMI2	miser	Weedy milkvetch
ASMI3	missouriensis	Missouri milkvetch
ASMO	moencoppensis	Moenkopi milkvetch
ASMO2	mohavensis	Mohave milkvetch
ASMO5	mokiacensis	Mokiak milkvetch
ASMO6	mollissimus	Woolly milkvetch
ASMO3	monoensis	Mono milkvetch
ASMO4	monumentalis	Monument valley milkvetch
ASMU	mulfordiae	Mulford milkvetch
ASMU2	musiniensis	Musinea milkvetch
ASNA	naturitensis	Naturita milkvetch
ASNE2	nelsonianus	
ASNE	newberryi	Newberry milkvetch
ASNI	nidularius	Birdnest milkvetch
ASNU	nudisiliquus	Cobblestone milkvetch
ASTRA	Astragalus spp.	(con.)
ASNU2	nuttallianus	Nuttall milkvetch
ASNY	nyensis	Nye milkvetch
ASOB	obscurus	Arcane milkvetch
ASON	oniciformis	Spindle milkvetch
ASOO	oophorus	
ASPA5	panamintensis	
ASPA6	pardalinus	Panther milkvetch
ASPA4	pattersonii	Patterson locoweed
ASPA7	paysonii	
ASPE2	pectinatus	Narrowleaf poisonvetch
ASPE3	perianus	Bullion Creek milkvetch
ASPI	pinonis	Pinon milkvetch
ASPL	platytropis	Broadkeeled milkvetch
ASPO	podocarpus	
ASPO2	porrectus	Lahontan milkvetch
ASPR2	praelongus	Stinking milkvetch
ASPR3	preussii	Preuss milkvetch
ASPS	pseudiodanthus	Tonopah milkvetch
ASPT	pterocarpus	Winged milkvetch
ASPU3	pubentissimus	Greenriver milkvetch
ASPU2	pulsiferae	Ames milkvetch
ASPU	purshii	Pursh locoweed
ASRA	racemosus	Alkali milkvetch
ASRA2	rafaelensis	San Rafael milkvetch
ASRE	recedens	
ASRE2	recurvus	Recurved milkvetch
ASRE3	refractus	Texas milkvetch
ASRE4	remotus	Springmountain milkvetch
ASRE5	reventus	Bluemountain milkvetch
ASRO	robbinsii	Robbins milkvetch
ASRU4	rusbyi	Rusby milkvetch
ASSA	sabulonum	Cisco milkvetch
ASSA2	sabulosus	Straightstem poisonvetch
ASSA3	salmonis	Troutcreek milkvetch
ASSA4	saurinus	Dinosaur milkvetch
ASSC2	scopulorum	
ASSC3	scorpoidies	Rocky Mountain milkvetch
ASSE2	serenoi	Naked milkvetch

ASTRA	Astragalus spp.	Loco
ASSE5	serpens	Plateal milkvetch
ASSE4	sesquiflorus	Sandstone milkvetch
ASSO	solitarius	Solitary milkvetch
ASSO2	sophoroides	Painted desert milkvetch
ASSP5	spatulatus	Tufted milkvetch
ASST2	sterilis	Barren milkvetch
ASST3	stipulatus	
ASST6	stocksii	
ASST4	straturensis	Pinevalley milkvetch
ASST5	striatiflorus	Escarpment milkvetch
ASSU3	subcinereus	Silar milkvetch
ASTE	tegetarioides	Bastard milkvetch
ASTE2	tegetarius	Mat milkvetch
ASTE3	tenellus	Looseflower milkvetch
ASTE4	tephrodes	Towline loco
ASTE5	terminalis	Railhead milkvetch
ASTE6	tetrapterus	Fourwing poisonvetch
ASTI	tidestromii	Tidestrom milkvetch
ASTO	toanus	Toano milkvetch
ASTO2	toquimanus	Toquima milkvetch
ASTR2	trimestris	
ASTR3	troglodytus	Cliffdweller milkvetch
ASUN	uncialis	Currant milkvetch
ASUT	utahensis	Utah locoweed
ASVEN	vexilliflexus nubilus	Bentflowered milkvetch
ASWA2	wardii	Ward locoweed
ASWE	wetherillii	Weatherill milkvetch
ASWH	whitneyi	Balloon milkvetch
ASWI	wingatanus	Fortwingate milkvetch
ASWO	woodruffii	Woodruff milkvetch
ASWO2	wootonii	Wooton locoweed
ASXI	xiphoides	Gladiator milkvetch
ASZI	zionis	Zion milkvetch

ATHYR	Athyrium spp.	Ladyfern
ATDI2	distentifolium	Alpine ladyfern
ATFI	filix-femina	Ladyfern
ATHYS	Athysanus spp.	Sandweed
ATPU	pusillus	
ATRIC	Atrichoseris spp.	Tobacco weed
ATPL	platyphylla	
ATRIP	Atriplex spp.	Saltbush
ATAR	argentea	Tumbling saltbush
ATDI	dioeca	Scurfless saltbush
ATEL	elegans	Wheelscale saltbush
ATGR	graciliflora	
ATHO	hortensis	Garden orach
ATPA2	patula	Fat-hen saltbush
ATPH	phyllostegia	
ATPO2	powellii	
ATPU2	pusilla	
ATRO	rosea	Tumbling orach
ATSA	saccaria	
ATSE	semibaccata	Australian saltbush
ATSE2	serenana	
ATTE	tenuissima	
ATWO	wolfii	Wolf saltbush
AZOLL	Azolla spp.	Azolla
AZME	mexicana	Mexican azolla
BACOP	Bacopa spp.	Waterhyssop
BAEI	eisenii	
BARO	rotundifolia	Disk waterhyssop
BAHIA	Bahia spp.	Bahia
BADI	dissecta	Ragleaf bahia
BANU	nudicaulis	Basin bahia
BAOB	oblongifolia	
BAOU	ourolepis	
BAILE	Baileya spp.	Baileya
BAMU	multiradiata	Desert baileya
BAPA	pauciradiata	
BAPE	perennis	Leafystem baileya
BAPL	pleniradiata	Desert marigold baileya
BALSA	Balsamorhiza spp.	Balsamroot
BAHI	hirsuta	Hairy balsamroot

BALSA	Balsamorhiza spp. (con.)	
BAHOH	hookeri hookeri	Hooker balsamroot
BAHO2	hookeri hispidula	
BAHOI	hookeri idahoensis	
BAHON	hookeri neglecta	
BAIN	incana	Hoary balsamroot
BAMA	macrophylla	Cutleaf balsamroot
BASA	sagittata	Arrowleaf balsamroot
BASE	serrata	Serrated balsamroot
BARBA	Barbarea spp.	Wintercress
BAOR	orthoceras	Erectpod wintercress
BASSI	Bassia spp.	Bassia
BAHY	hyssopifolia	Fivehook bassia
BELLI	Bellis spp.	Daisy
BEPE	perennis	English daisy
BERUL	Berula spp.	Berula
BEER	erecta	Stalky berula
BESSE	Besseya spp.	Kittentails
BEAL	alpina	Alpine kittentails
BERU	rubra	Red besseya
BEWY	wyomingensis	Wyoming kittentails
BETA	Beta spp.	Beet
BEVU	vulgaris	Common beet
BIDEN	Bidens spp.	Beggarticks
BIBI	bipinnata	Spanish-needles
BICE	cernua	Nodding beggarticks
BIFR	frondosa	Devils beggarticks
BLEP2	Blepharipappus spp.	
BLSC	scaber	
[illegible]	[illegible] spp.	
BOMI	microcarpa	
BOERH	Boerhaavia spp.	Spiderling
BOAN	annulata	Wetleaf spiderling
BOERH	Boerhaavia spp. (con.)	
BOCO	coulteri	Coulter spiderling
BOLE	leiosolena	
BOTO	torreyana	Torrey spiderling
BOWR	wrightii	Wright spiderling
BOISD	Boisduvalia spp.	Spikeprimrose
BODE	densiflora	Dense spikeprimrose
BOGL	glabella	
BOMA	macrantha	
BOPA	pallida	
BOST	stricta	Brook spikeprimrose
BOLAN	Bolandra spp.	Bolandra
BOOR	oregana	Oregon bolandra
BORAG	Borago spp.	Borage
BOOF	officinalis	Common borage
BOTRY	Botrychium spp.	Grapefern
BOBOO	boreale obtusilobum	Northern grapefern
BOLA	lanceolatum	Lanceleaved grapefern
BOLU	lunaria	Moonwort
BOMA2	matricariaefolium	Matricary grapefern
BOSI	simplex	Little grapefern
BOVI	virginianum	Rattlesnake fern
BRASS	Brassica spp.	Mustard
BRCA3	campestris	Bird rape
BRHI	hirta	White mustard
BRJU	juncea	India mustard
BRKA	kaber	Charlock
BRNI	nigra	Black mustard
BRICK	Brickellia spp.	
BRGR	grandiflora	Tasselflower brickellia
BROB	oblongifolia linifolia	Mohave brickellia
BRODI	Brodiaea spp.	Brodiaea
BRDO	douglasii	Douglas brodiaea
BRHY	hyacintha	Hyacinth brodiaea

[illegible]	Brodiaea spp.	[illegible]
[illegible]	pulchella	[illegible]applehead brodiaea
BRYON	Bryonia spp.	Bryony
BRAL	alba	White bryony
BUTOM	Butomus spp.	Flowering rush
BUUM	umbellatus	Flowering rush
CALAN	Calandrinia spp.	Rockpurslane
CACI	ciliata	Redmaids rockpurslane
CALLI	Callirhoe spp.	Poppy mallow
CAIN	involucrata	Low poppy mallow
CALLI	Callitriche spp.	Waterstarwort
CAHE	hermaphroditica	
CAHE2	heterophylla	Larger waterstarwort
CAVE	verna	
CALOC	Calochortus spp.	Mariposa lily
CAAM	ambiguus	
CAAU3	aureus	Golden segolily mariposa lily
CAEL2	elegans	Northwestern mariposa lily
CAEU	eurycarpus	Big-pod mariposa lily
CAFL	flexuosus	Weakstem mariposa lily
CAGU	gunnisonii	Gunnison mariposa lily
CAKE	kennedyi	Desert mariposa lily
CALE7	leichtlinii	Smokey mariposa lily
CAMA	macrocarpus	Sagebrush mariposa lily
CANI	nitidus	Broadfruit mariposa lily
CANUN	nuttallii	Segolily
	nuttallii	mariposa lily
CAST	striatus	
CALTH	Caltha spp.	Marshmarigold
CALE	leptosepala	Elkslip marshmarigold
CALYC	Calycoseris spp.	
CAPA	parryi	
CAWR	wrightii	
CALYP	Calypso spp.	Calypso
CABU2	bulbosa	Fairy slipper orchid
CALY2	Calyptridium spp.	Calyptridium
CAMO2	monandrum	
CAPA2	parryi	

[illegible]	[illegible]	[illegible]
[illegible]	rosea	[illegible] calyptridium
CAMA	Camassia spp.	Camas
CALE3	leichtlinii	Leichtlin camas
CAQU	quamash	Common camas
CAMEL	Camelina spp.	Falseflax
CAMI2	microcarpa	Littlepod falseflax
CAMIS	Camissonia spp. (Oenothera)	
CAAN	andina	Andean evening primrose
CABOA	boothii alyssoides	Alyssum evening primrose
CABR	brachycarpa	
CABR6	brevipes	Golden evening primrose
CACA10	californica	Desert evening primrose
CACH4	chamaenerioides	
CACL2	claviformis	Browneyed evening primrose
CACO6	contorta	Plains evening primrose
CADE3	decorticans	
CADE4	dentata	
CAEA	eastwoodiae	
CAFL4	flava	Yellow evening primrose
CAHE7	heterantha	
CAHE8	heterochroma	
CAME2	megalantha	
CAMI7	micrantha	
CAMI8	minor	Small evening primrose
CAMU3	multijuga	
CAMU4	munzii	
CAPA8	palmeri	
CAPA9	parryi	
CAPT	pterosperma	
CARE2	refracta	
CASC2	scapoidea	Barestem evening primrose
CASP3	specuicola	
CATA	tanacetifolia	Tansyleaf evening primrose
CAWA	walkeri	
CAMPA	Campanula spp.	Bellflower
CAPA3	parryi	Parry bellflower
CARA	rapunculoides	Creeping bellflower
CARO2	rotundifolia	Bluebell
CATR	trubinata	
CAUN	uniflora	
CANBY	Canbya spp.	Canby poppy
CAAU	aurea	Golden canby poppy

CANNA	Cannabis spp.	Hemp or marijuana
CASA	sativa	Hemp
CAPSE	Capsella spp.	Shepherds purse
CABU	bursa-pastoris	Shepherds-purse
CARDA	Cardamine spp	Bittercress
CABE	bellidifolia	
CABR	breweri	Brewer bittercress
CACO	cordifolia	Heartleaf bittercress
CALY	lyallii	Lyall bittercress
CAOC	occidentalis	Western bittercress
CAPA4	parviflora	
CAPE4	pennsylvanica	Pennsylvania bittercress
CARD2	Cardaria spp	Whitetop
CADR	draba	Pepperweed whitetop
CAPU2	pubescens	Longstalk hairy whitetop
CARDU	Carduus spp	Bristlethistle
CANU	nutans	Musk bristlethistle
CARTH	Carthamus spp.	
CATI	tinctorius	Safflower
CARUM	Carum spp	
CACA6	carvi	Caraway
CASTI	Castilleja spp	Indian paintbrush, painted-cup
CAAN	angustifolia	Northwestern painted-cup
CAAP3	applegatei	Pine Indian paintbrush
CAAR5	arachnoidea	
CABA	barnebyana	
CACA7	calcicola	
CACH2	chlorotica	
CACH3	chromosa	Desert Indian paintbrush
CACH4	chrysantha	
CACL	clokeyi	
CACO5	covilleana	
CACU2	cusickii	Scarlet painted-cup
CAEL3	elkoensis	
CAEX3	exilis	
[illegible]	flava	Yellow Indian paintbrush

CASTI	Castilleja spp.	con.
CAFR	fraterna	
CAGL	glandulifera	Grand Indian paintbrush
CAGR	gracillima	Slender Indian paintbrush
CAHI	hispida	Northwestern painted-cup
CAIN5	integra	Wholeleaf painted cup
CAKA	kaibabensis	
CALA4	lanata	
CALA5	lapidicola	
CALE	leonardi	
CALI	linariaefolia	Wyoming painted-cup
CALO2	longispica	
CAMA2	magnistylis	
CAMI5	miniata	Scarlet painted cup
CAMI6	minor	
CANA	nana	
CAOC3	occidentalis	Western painted cup
CAOR	oreshia	Pale wallowa paintbrush
CAPA7	pallescens	Pale painted-cup
CAPI2	pilosa	White painted-cup
CAPR6	pruinosa	
CAPU3	puberula	
CAPU4	pulchella	
CAPY2	pyramidalis	
CARE2	revealii	
CARH	rhexifolia	Splitleaf painted-cup
CARU3	rustica	
CASA3	salsuginosa	
CASC4	scabrida	
CASU	sulphurea	Sulphur painted cup
CATR3	trainii	
CAVI2	viscida	
CAVI3	viscidula	
CAUCA	Caucalis spp.	False-carrot
CAMI7	microcarpa	False carrot
CAULA	Caulanthus spp. (See Streptanthus	Wildcabbage
CACO6	cooperi	
CACR	crassicaulis	Thickstem wildcabbage
CAGL2	glaber	
CAGL3	glaucus	
CAMA3	major	
CAPI3	pilosus	

FORBS

CENTA	Centaurea spp.	Centaurea
CECA	calcitrapa	Star thistle
CECY	cyanus	Cornflower
CEDE2	dealbata	Persian centaurea
CEDI	diffusa	Diffuse knapweed
CEJA	jacea	Brownscale centaurea
CEMA2	macrocephala	Globe centaurea
CEOX	oxylepis	
CEPE	pennsylvanica	
CERE2	repens	Russian centaurea
CESO	solstitialis	Yellow centaurea
CEVI	virgata	
CENT2	Centaurium spp	Centaurium
CECA2	calycosum	
CECU	curvistamineum	
CEEX	exaltatum	
CENU	nuttallii	
CERAS	Cerastium spp	Cerastium, mouse-ear chickweed
CEAR	arvense	Starry cerastium
CEBE	beeringianum	
CEBR	brachypodum	
CENU2	nutans	Nodding cerastium
CEVI2	viscosum	Sticky cerastium
CEVU	vulgatum	Big cerastium
CERA1	Ceratophyllum spp	Hornwort
CEDE3	demersum	Hornwort
CHAEN	Chaenactis spp.	Chaenactis or Dusty maiden
CHAL4	alpigena	
CHAL2	alpina	Alpine dusty maiden
CHCA2	carphoclinia	
CHCU	cusickii	
CHDO	douglasii	Douglas chaenactis
CHEV	evermannii	
CHFR	fremontii	
CHMA	macrantha	
CHNE	nevadensis	
CHST3	stevioides	
CHXA	xantiana	
CHEAT	Chaetadelpha spp	
CHWH	wheeleri	

FORBS

CHAM2	Chamaechaenactis spp	
CHSC	scaposa	
CHAM3	Chamaerhodos spp	
CHER	erecta	
CHAM4	Chamaesaracha spp	
CHCO	coronopus	
CHNA3	nana	
CHEI1	Cheilanthes spp	Lipfern
CHCO2	covillei	Coville lipfern
CHEA	eatoni	Eaton lipfern
CHFE	feei	Fee lipfern
CHFE2	fendleri	Fendler lipfern
CHGR	gracillima	Lace lipfern
CHWO	wootonii	
CHEL1	Chelidonium spp.	Celandine
CHMA2	majus	Greater celand
CHENO	Chenopodium spp.	Pigweed or Goosefoot
CHAL3	albescens	
CHAL	album	Lambsquarters goosefoot
CHAM	ambrosioides	Wormseed goosefoot
CHAR	aridum	
CHAT	atrovirens	Dark goosefoot
CHBE	berlandieri	Pitseed goosefoot
CHBO	botrys	Jerusalem oak goosefoot
CHCA	capitatum	Blite goosefoot
CHCH	chenopodioides (rubrum)	Red goosefoot
CHDE2	dessicatum	Desert goosefoot
CHFO2	foliosum	
CHFR2	fremontii	Fremont goosefoot
CHGI	gigantospermum (hybridum)	Mapleleaf goosefoot
CHGL	glaucum	Oakleaf goosefoot
CHHI	hians	
CHHU	humile	
CHIN	incanum	
CHIN2	incognitum	
CHLE	leptophyllum (chamoenum)	Slimleaf goosefoot
CHMU	murale	Nettleleaf goosefoot
CHNE2	nevadense	
CHOV	overi	
CHPA2	palmeri	
CHST2	strictum	
CHSU	subglabrum	

CHENO	Chenopodium spp. (con.	
CHWA	watsonii	
CHIMA	Chimaphila spp	Pipsissewa
CHUMO	umbellata occidentalis	Western pipsissewa
CHINO	Chionophila spp	
CHTW	tweedyi	Snowlover
CHLO2	Chlorocrambe spp.	(Sisymbrium)
CHHA	hastata	
CHLI2	linifolium	
CHORI	Chorispora spp.	Chorispora or Blue mustard
CHTE	tenella	
CHOR2	Chorizanthe spp	Turksrug spineflower
CHBR2	brevicornu	
CHRI	rigida	
CHTH	thurberi	Thurber spineflower
CHWA2	watsonii	Watson spineflower
CHRYS	Chrysanthemum spp	Chrysanthemum
CHAR2	arcticum	Arctic chrysanthemum
CHBA	balsamita	Costmary chrysanthemum
CHLE2	leucanthemum	Oxeye-daisy
CHRY2	Chrysopsis spp	(see Heterotheca)
CICHO	Cichorium spp	Chicory
CIIN	intybus	Common chicory
CICUT	Cicuta spp	Waterhemlock
CIDO	douglasii	Douglas waterhemlock
CIMA	maculata	Spotted waterhemlock
CIRCA	Circaea spp	Circaea
CIAL	alpina	Alpine circaea
CIRSI	Cirsium spp	Thistle
CIAN	andersonii	Anderson thistle
CIAR	arizonicum	Arizona thistle
CIAR2	arvense	Canada thistle
CIBI	bipinnatum	
CIBR	brevifolium	
CICA	calcareum	
CICA2	canovirens	
CIRSI	Cirsium spp. (con.)	
CICE	centaurea	Fringed thistle
CICL	clavatum	
CIDA	davisii	
CIDO2	douglasii	
CIEA	eatonii	
CIFL	flodmanii	Flodman thistle
CIFO	foliosum (drummondii)	Elk thistle
CIHA	hallii	Halls thistle
CIIN2	inamoenus	
CIMO	mohavense	Mohave thistle
CINI	nidulum	
CIOC	ochrocentrum	Yellow thistle
CIPA	parryi	
CIPO	polyphyllum	
CIPR	proteanum	
CIPU	pulchellum	
CIRO	rothrockii	
CIRY	rydbergii	
CISC	scopulorum	Carmine thistle
CISU	subniveum	
CIUM	undulatum	Wavyleaf thistle
CIUT	utahense	
CIVU	vulgare	Bull thistle
CLARK	Clarkia spp.	Clarkia
CLLA2	lassenensis	
CLPU	pulchella	Deerhorn clarkia
CLRH	rhomboidea	Rhomboid clarkia
CLAYT	Claytonia spp.	Springbeauty
CLLA	lanceolata	Lanceleaf springbeauty
CLME	megarrhiza	Alpine springbeauty
CLNE	nevadensis	Nevada springbeauty
CLUM	umbellata	
CLEMA	Clemans spp	
CLDO	douglassi.	
CLEM2	Clematis spp	
CLCO	columbiana	Virgin bower
CLHIH	hirsutissima hirsutissima (douglasii)	Douglas clematis
CLHIS	hirsutissima scottii	Scott clematis
CLLI2	ligusticifolia	Western virginsbower

CLOM	Cleome spp.	Spiderflower
CLLU	lutea	Yellow spiderflower
CLPL	platycarpa	
CLSE	serrulata	Bee spiderflower
CLSP	sparsifolia	Scanty spiderflower
CLEO2	Cleomella spp.	Cleomella
CLBR2	brevipes	
CLHI	hillmanii	Hillman cleomella
CLOB	obtusifolia	
CLPA	palmerana	Palmer cleomella
CLPA2	parviflora	Slender cleomella
CLPL2	plocasperma	
CLINT	Clintonia spp.	Beadlily
CLUN	uniflora	Queencup or cornlily
CNIC	Cnicus spp.	Blessed thistle
CNBE	benedictus	Blessed thistle
COLDE	Coldenia spp.	Coldenia
COCA	canescens	Spreading coldenia
COHI	hispidissima	Hairy coldenia
CONU	nuttallii	Nuttall coldenia
COPL	plicata	[illegible] mat coldenia
COLLI	Collinsia spp.	Blue-eyed Mary
COCH	childii	
COGR	grandiflora	Bluelips collinsia
COPA2	parviflora	Littleflower collinsia
COTO	torreyi	
COLLO	Collomia spp.	Collomia
CODE	debilis	Alpine collomia
COGR2	grandiflora	Bigflower collomia
COLI	linearis	Slenderleaf collomia
COTE	tenella	[illegible] collomia
COTI	tinctoria	Yellowstaining collomia
COMAN	Comandra spp.	Comandra
COPA	pallida	Bastard toadflax
COMME	Commelina spp.	Dayflower
CODI	dianthifolia	Birdbill dayflower
CONIO	Conioselinum spp.	Hemlock-parsley
COSC	scopulorum	Rock. Mt. hemlock-parsley

CONIU	Conium spp.	
COMA	maculatum	Poison hemlock
CONR	Conringia spp.	Haresear
COOR	orientalis	Treacle haresear
CONV	Convolvulus spp.	Glorybind, Bindweed, or Morning glory
COAR	arvensis	European glorybind
COLO	longipes	
COSE	sepium	Hedge glorybind
CONY2	Conyza spp.	Horseweed
COCA2	canadensis	Canadian horseweed
CORAL	Corallorrhiza spp.	Coralroot
COMA2	maculata	Spotted coralroot
COME	mertensiana	Pacific coralroot
COST	striata	Hooded coralroot
COTR	trifida	Early coralroot
COWI	wisteriana	Wister coralroot
CORDY	Cordylanthus spp.	Birdbeak
COCA3	canescens	
COCA4	capitatus	Clustered birdbeak
COHE	helleri	Heller birdbeak
COKI	kingii	King birdbeak
COLA	laxiflorus	
CONE	nevadensis	Nevada birdbeak
COPA3	parviflorus	
CORA	ramosus	Bush birdbeak
COTE2	tecopensis	
COTE3	tenuifolius	Slender birdbeak
COTE4	tenuis	
COWR	wrightii	Wright birdbeak
COREO	Coreopsis spp.	Coreopsis
COLA2	lanceolata	Lance coreopsis
COTI	tinctoria	Plains coreopsis
CORIA	Coriandrum spp.	Coriander
COSA	sativum	Coriander
CORIS	Corispermum spp.	Tickseed, or Bugseed
COEM	emarginatum	
COHY	hyssopifolium	Hyssopleaf tickseed
CONI	nitidum	Shiny tickseed
COVI	villosum	

COMI	minima	Small crownvetch coronilla
COVA	varia	Crownvetch coronilla
CORYD	Corydalis spp	Corydalis
COAU	aurea	Golden corydalis
COAUM	montanum	Mountain corydalis
COCA5	caseana	Fitweed corydalis
CORYP	Coryphantha spp.	Coryphantha
COMI2	missouriensis	Nipple coryphantha
COVI2	vivipara vivipara	Cushion coryphantha
COVIA	vivipara arizonica	Arizona cushion coryphantha
COVID	vivipara desertii	Desert cushion coryphantha
CREPI	Crepis spp.	Hawksbeard
CRAC	acuminata	Tapertip hawksbeard
CRAT	atrabarba	Slender hawksbeard
CRBA	bakeri	Baker hawksbeard
CRBA2	barbigera	Bearded hawksbeard
CRIN	intermedia	Gray hawksbeard
CRMO	modocensis	Modoc hawksbeard
CRMO2	monticola	Siskiyou hawksbeard
CROC	occidentalis	Western hawksbeard
CRRUG	runcinata glauca	Dandelion hawksbeard
CRSC	scopulorum	Yellowstone hawksbeard
CRESS	Cressa spp.	
CRTR	truxillensis	
CROTO	Croton spp.	Croton
CRCA	californicus	California croton
CRTE	texensis	Texas croton
CRYPT	Cryptantha spp.	Cryptantha
CRAB	abata	
CRAF	affinis	
CRAM	ambigua	Wilkes cryptantha
CRAN	angustifolia	
CRBA3	bakeri	Baker cryptantha
CRBA4	barbigera	
CRBA5	barnebyi	Barneby cryptantha
CRBR	breviflora	
CRCA2	caespitosa	Tufted cryptantha
CRCA3	capitata	
CRCI	circumscissa	Matted cryptantha

CRCO	confertiflora	
CRCR	crassisepala	Plains hiddenflower
CRDE	decipiens	
CRDO	dolosa	
CRDU	dumetorum	
CREC	echinella	
CREC2	echinoides	
CRFL	fendleri	Fendler cryptantha
CRFL3	flaccida	Weakstem cryptantha
CRFL2	flava	Yellow cryptantha
CRFL	flavoculata	Roughseed cryptantha
CRFU	fulvo canescens	Beggarlice hiddenflower
CRGL	glomeriflora	
CRGR	gracilis	
CRGR2	grahamii	
CRHO	hoffmannii	
CRHU	humilis	
CRIN2	inaequata	
CRIN3	insolita	
CRIN4	interrupta	
CRJA	jamesii	James cryptantha
CRJO	jonesiana	
CRKE	kelseyana	Kelsey cryptantha
CRLO	longiflora	
CRMA	maritima	
CRME	mensana	
CRMI	micrantha	Desert nut
CRMI2	mirabunda	
CRMU	muricata	
CRNA	nana	
CRNE	nevadensis	
CRNU	nubigena	
CROS	osterhoutii	
CROX2	oxygona	
CRPA	paradoxa	
CRPA2	pattersonii	
CRPR	propria	Idaho cryptantha
CRPT	pterocarya	Winged cryptantha
CRRA	racemosa	Forget-me-not cryptantha
CRRE	recurvata	
CRRO	rollinsii	
CRRU	rugulosa	
CRSA	salmonensis	Salmon River cryptant
CRSC2	scoparia	Desert cryptantha
CRSE2	semiglabra	
CRSE	sericea	
CRSE3	setosissima	
CRSI	simulans	Pine woods cryptantha
CRSU	subretusa	

FORBS

CRYPT	Cryptantha spp. (con.)	
CRTE2	tenuis	
CRTO	torreyana	Torrey cryptantha
CRUT	utahensis	
CRVI	virginensis	
CRWA	watsonii	Watson cryptantha
CRWE	wetherillii	
CRYP2	Cryptogramma spp	Rockbrake
CRAC2	acrostichoides	American rockbrake
CRST	stelleri	Slender rockbrake
CUCUR	Cucurbita spp.	Gourd
CUFO	foetidissima	Buffalogourd
CUSCU	Cuscuta spp.	Dodder
CUAP	approximata	
CUCA	californica	
CUCA2	campestris	Legume dodder
CUCE	cephalanthi	Button dodder
CUCO	coryli	Hazel dodder
CUCU	curta (megalocarpa)	
CUCU2	cuspidata	
CUDE	denticulata	
CUEP	epithymum	Clover dodder
CUGR	gronovii	Gronovius dodder
CUIN	indecora	Bigseed alfalfa dodder
CUNE	nevadensis	
CUOC	occidentalis	
CUPE	pentagona	
CUSA	salina	Saltmarsh dodder
CUWA	warneri	
CYCLO	Cycloloma spp.	Ringwing
CYAT	atriplicifolium	Tumble ringwing
CYMOP	Cymopterus spp.	Spring parsley
CYAB	aboriginum	Indian spring parsley
CYAC	acaulis	Stemless spring parsley
CYAN	anisatus	Anis spring parsley
CYBA	basalticus	Basalt spring parsley
CYBI	bipinnatus	Fernleaf spring parsley
CYBU	bulbosus	Onion spring parsley
CYCI	cinerarius	Great Basin spring parsley
CYCO	corrugatus	
CYCO2	coulteri	Coulteri spring parsley
CYDU	duchesnensis	Utah spring parsley
CYFE	fendleri	Chimaya
CYGI	gilmanii	Gilman spring parsley

FORBS

CYMOP	Cymopterus spp. (con.)	
CYGL	glaucus	Smooth spring parsley
CYGL2	globosus	
CYGR	grayii	
CYHE	hendersonii	Henderson spring parsley
CYHI	higginsii	
CYIB	ibapensis	
CYJO	jonesii	Jones spring parsley
CYLO	longipes	
CYME	megacephalus	
CYMI	minimum	
CYMU	multinervatus	Corkwing spring parsley
CYNE	newberryi	Sweetroot spring parsley
CYNI	nivalis	
CYPE	petraeus	
CYPU	purpurascens	Purple spring parsley
CYPU2	purpureus	
CYRI	ripleyi	
CYRO	rosei	
CYTE	terebinthina	
CYWA	watsoni	Watson spring parsley
CYNAN	Cynanchum spp.	Swallow-wort
CYUT	utahense	
CYNOG	Cynoglossum spp.	Houndstongue
CYOF	officinale	Common houndstongue
CYPRI	Cypripedium spp.	Ladyslipper
CYCA	calceolus	Large yellow ladyslipper
CYCA2	californicum	California ladyslipper
CYFA	fasciculatum	Brownie ladyslipper
CYMO	montanum	Mountain ladyslipper
CYSTO	Cystopteris spp.	Bladderfern
CYBU2	bulbifera	Berry bladderfern
CYFR	fragilis	Brittle bladderfern
CYMO2	montana	Mountain bladdersenna

DALEA	Dalea spp. (Petalostemon)	Indigo bush, dalea, Parry dalea, Prairie-clover
DACA4	candidum	
DAEP	epica	
DAFL	flavescens	Yellow prairie clover
DAFR2	fremontii	
DAOR	ornatum	
DAPA	parryi	Parry dalea
DASE	searlsiae	Searls prairie clover
DAWH	whitingii	Whiting dalea
DATUR	Datura spp.	Datura, jimsonweed
DAME	meteloides	Sacred datura
DAST	stramonium	Jimsonweed, datura
DAUCU	Daucus spp.	Carrot
DACA2	carota	Wildcarrot
DASA	sativa	Garden carrot
DELPH	Delphinium spp.	Larkspur
DEAJ	ajacis	Rocket larkspur
DEAN	andersonii	Anderson larkspur
DEBA	barbeyi	Barbey larkspur
DEBI	bicolor	Little larkspur
DEBU	burkei	Burkes larkspur
DECY	cyanoreios	
DEDE	depauperatum	Slim larkspur
DEDI	diversifolium	Slender larkspur
DEGE	geyeri	Geyer larkspur
DEGL	glaucum	Sierra larkspur
DENE	nelsonii (menziesii)	Nelson larkspur
DENU	nuttallianum	Nuttall larkspur
DEOC	occidentale	Duncecap larkspur
DEPA	parishii	Parish larkspur
DEPO	polycladon	
DESC	scaposum	Barestem larkspur
DESO2	sonnei	Sonne larkspur
DEST	stachydeum	Rocky Mountain larkspur
DEUM	umatillense	
DEVI	virescens	Plains larkspur
DESCU	Descurainia spp.	Tansymustard
DECA2	californica	California tansymustard
DEOB	obtusa	
DEPI	pinnata	Pinnate tansymustard
DERI	richardsonii (hartwegiana)	Richardson tansymustard
DESCU	Descurainia spp. (con.)	
DESO	sophia	Flixweed tansymustard
DIANT	Dianthus spp.	Pink, carnation
DIPI	pinifolius	Pineleaf pink
DICEN	Dicentra spp.	Bleedingheart
DICU	cucullaria	Dutchman's breeches
DIUN	uniflora	Steershead
DICOR	Dicoria spp.	
DIBR	brandegei	
DICA	canescens	
DIPA	paniculata	
DIWE	wetherillii	
DICTA	Dictamnus spp.	Dittany
DIAL	albus	
DIMER	Dimeresia spp.	
DIHO	howellii	
DIPLO	Diplotaxis spp.	Wall rocket
DIMU	muralis	Stinking wall rocket
DIPSA	Dipsacus spp.	Teasel
DISY	sylvestris	Venus-cup teasel
DISPO	Disporum spp.	Fairybells
DIHO2	hookeri	Hooker fairybells
DITR	trachycarpum	Wartberry fairybells
DITHY	Dithyraea spp.	Spectacle-pod
DICA2	californica	California spectacle-pod
DIWI	wislizenii	Wislizenus spectacle pod
DODEC	Dodecatheon spp.	Shootingstar
DOAL	alpinum	Alpine shootingstar
DOCO	conjugens	Sailorscaps shootingstar
DODE	dentatum	Dentate shootingstar
DOJE	jeffreyi	Jeffrey shootingstar
DOPU	pulchellum	Darkthroat shootingstar
DORE	redolens	
DOWNI	Downingia spp.	Downingia
DOBA	bacigalupii	
DOBI	bicornuta	
DOEL	elegans	

DOWNI	Downingia spp.	(con.)
DOIN	insignis	
DOLA	laeta	
DRABA	Draba spp.	Draba
DRAR	argyrea	
DRAR2	arida	
DRAS	asprella	
DRAS2	asterophora	
DRAU	aurea (luteola)	Golden draba
DRBR	brachystylis	Short fruited draba
DRBR2	breweri	Brewer's draba
DRCR	crassa	
DRCR2	crassifolia	Hairy whitlowgrass
DRCU	[illegible]	
DRDEA	densifolia apiculata	Rockcress draba
DRDO	douglasii	Douglas draba
DRFL	fladnizensis	Arctic draba
DRIN	incerta	Yellowstone draba
DRLA	lanceolata	Lanceolate draba
DRMA	maguirei	
DRNE	nemorosa	Woods draba
DRNI	nivalis	Snow draba
DROLP	oligosperma pectinipita	Snowbank draba
DROR	oreibata	Limestone draba
DRPA	paysonii	Payson draba
DRPE	pectinipila	
DRPR	praealta	
DRQU	quadricostata	
DRRE	rectifructa	Mountain draba
DRRE2	reptans	Carolina draba
DRSO	sobolifera	Showy draba
DRSP	spectabilis	
DRSP2	sphaerocarpa	Globefruited draba
DRST	stenoloba	Alaska draba
DRSU	subalpina	Skinny draba
DRVE2	ventosa	
DRVE	verna	Spring draba
DRZI	zionensis	Utah draba
DRACO	Dracocephalum spp.	Dragonhead
DRNU	nuttallii	American dragonhead
DROSE	Drosera spp.	Sundew
DRAN	anglica	English sundew
DRRO	rotundifolia	Roundleaf sundew
DRYOP	Dryopteris spp.	Woodfern
DRDI	dilatata	Mountain woodfern
DRFI	filixmas	Male fern
DRYOP	Dryopteris spp.	(con.)
DRIN2	intermedia	Common woodfern
DRSP3	spinulosa	Toothed woodfern
DUDLE	Dudleya spp.	Dudleya
DUAR	arizonica	Arizona dudleya
DYSSO	Dyssodia spp.	Dogweed
DYAC	acerosa	Prickleaf dogweed
DYCO	cooperi	
DYPE	pentachaeta	
DYPO	porophylloides	
DYTH	thurberi	Thurber dogweed
EATON	Eatonella spp.	Eatonella
EANI	nivea	Sierra eatonella
EBURO	Eburophyton spp.	Phantom orchid
EBAU	austinae	Austin phantom orchid
ECHI4	Echinocystis spp.	Mock-cucumber
ECLO	lobata	Wild mock-cucumber
ECHI5	Echinodorus spp.	Burhead
ECBE	berteroi	Burhead
ECHI6	Echinops spp.	Globethistle
ECRI	ritro	Small globethistle
ECEX	exaltatus	Russian globethistle
ELATI	Elatine spp.	Waterwort
ELBR	brachysperma	Shortseed waterwort
ELRU	rubella	
EMMEN	Emmenanthe spp.	Whisperingbells
EMPA	parviflora	Sagebrush whisperingbells
EMPE	penduliflora	Yellow whisperingbells
ENCE2	Enceliopsis spp.	Enceliopsis
ENAR	argophylla	Silverleaf enceliopsis
ENNU	nudicaulis	Barestem enceliopsis
ENNU2	nutans	

FORBS

EPILO	Epilobium spp.	Willowweed
EPAD	adenocaulon	Sticky willowweed
EPAL	alpinum (hornemannii)	Alpine willowweed
EPAN	angustifolium	Fireweed
EPCI	ciliatum	
EPGL	glaberrimum	
EPGL2	glandulosum	Glandular willowweed
EPLA	latifolium	Red willowweed
EPMI	minutum	
EPOB	obcordatum	
EPPA2	palustre	
EPPA	paniculatum	Autumn willowweed
EPIPA	Epipactis spp	Epipactis
EPGI	gigantea	Stream epepactis
EQUIS	Equisetum spp.	Horsetail
EQAR	arvense	Field horsetail
EQFU	funstonii	Funston horsetail
EQHYC	hyemale californicum	Western scouring-rush
EQKA	kansanum	Kansas horsetail
EQLA	laevigatum	Smooth horsetail
EQPA	palustre	Marsh horsetail
EQPR	pratense	Meadow horsetail
EQVA	variegatum	Variegated horsetail
EREMO	Eremocrinum spp	
ERAL3	albomarginatum	
ERIAS	Eriastrum spp	Eriastrum
ERDE	densifolium	
ERDI2	diffusum	
ERER	eremicum	
ERSP	sparsiflorum	
ERIGE	Erigeron spp	Fleabane, daisy
ERAB	abajoensis	
ERAC	acris	Bitter fleabane
ERAP	aphanactis concinnus	Hairy fleabane
ERAR2	arenarioides	
ERAR	argentatus	
ERAS	asperugineus	
ERBE	bellidiastrum	
ERBL	bloomeri	Bloomer fleabane
ERBR	breweri	
ERCA3	caespitosus	Tufted fleabane

FORBS

ERIGE	Erigeron spp.	(con.)
ERCA2	canus	Hoary fleabane
ERCH2	chrysopsidis	Dwarf yellow fleabane
ERCL	clokeyi	
ERCO2	compactus	
ERCO3	compositus	Fernleaf fleabane
ERCO	corymbosus	Purpledaisy fleabane
ERCO4	coulteri	Coulter fleabane
ERCR	cronquistii	
ERDI3	disparipilus	
ERDI4	divergens	Spreading fleabane
EREA	eatonii	Eaton fleabane
EREL3	elatior	Tall fleabane
EREL4	elegantulus	
EREN	engelmannii	Engelmann fleabane
EREV	evermanii	Evermann daisy
ERFI	filifolius	Threadleaf fleabane
ERFL	flagellaris	Trailing fleabane
ERFO	formosissimus	Wild daisy
ERGA	garrettii	
ERGL	glabellus	Smooth fleabane
ERIN	inornatus	
ERJO	jonesii	
ERKA	kachinensis	
ERLA4	latus	
ERLE	leiomerus	Yellow fleabane
ERLO	lonchophyllus	Spearleaf fleabane
ERMA	macranthus	Aspen fleabane
ERMA2	maguirei	
ERMA3	mancus	
ERME2	melanocephalus	
ERNA	nanus	Dwarf fleabane
ERNA2	nauseosus	
ERNA3	navidincola	
EROV2	ovinus	
ERPE	peregrinus	Peregrine fleabane
ERPE2	petiolaris	
ERPH	philadelphicus	Philadelphia fleabane
ERPO	poliospermus	Cushion fleabane
ERPU	pulcherrimus	Basin fleabane
ERPU2	pumilus	Low fleabane
ERPY	pygmaeus	
ERRE	religiosus	
ERSI	simplex	Oneflower fleabane

[illegible]	[illegible]	[illegible]
ERSPM	speciosus macranthus	Oregon fleabane
ERST	strigosus	Rough fleabane
ERSU	subtrinervis	Three-nerve fleabane
ERSU	superbus	
ERTE	tener	
ERTW	tweedyi	
ERUI	uintahensis	
ERUN	uncialis	
ERUR	ursinus	Bear River fleabane
ERUT	utahensis	Utah fleabane
ERVA	vagus	
ERWA	watsonii	Watson fleabane
ERIO	Eriogonum spp	Eriogonum or wild buckwheat
ERAC2	acaule	
ERAL	alatum	Wing eriogonum
ERAM	ampullaceum	
ERAR3	arcuatum	
ERAR1	arenarioides	
ERAU	aureum	
ERBA	baileyi	Bailey wild buckwheat
ERBA3	batemanii	Bateman wild buckwheat
ERBI	bicolor	
ERBR2	brevicaule	Shortstem wild buckwheat
ERCA	caespitosum	Mat eriogonum
ERCA1	campanulatum	
ERCE	cernuum	Nodding eriogonum
ERCH	chrysocephalum	Goldball eriogonum
ERCL2	clavellatum	
ERCL3	clutei	
ERCO5	collinum	
ERCO6	compositum	Northern eriogonum
ERCO7	corymbosum	Corymbed eriogonum
ERDA	davidsonii	
ERDA2	davisianum	
ERDE2	deflexum	Skeletonweed wild buckwheat
ERDI3	divaricatum	
ERDO	douglasii	Douglas eriogonum
ERDU	duchesnense	
EREF	effusum	Rush eriogonum
EREL	elatum	
ERES	esmeraldense	
ERFA	fasciculatum	Flattop eriogonum
ERFI2	filicaule	
ERFL	flavum	Yellow eriogonum
ERGL2	glandulosum	
ERGO	gordonii	
ERHE	heermannii	Mojave eriogonum

[illegible]	[illegible]	[illegible]
ERHO	hookeri	
ERHO2	howellii	
ERIN	inflatum	Desert trumpet eriogonum
ERJA	jamesii	James eriogonum
ERJO	jonesii	Jones wild buckwheat
ERKE	kennedyi	Kennedy eriogonum
ERKE	kearneyi	
ERLA	lachnogynum	
ERLA3	latens	Inyo eriogonum
ERLE2	lemmonii	Lemmon wild buckwheat
ERLE3	leptocladon	
ERLE1	leptophyllum	Slender wild buckwheat
ERLO	lobbii	[illegible] eriogonum
ERLO3	loganum	
ERLO2	lonchophyllum	Umbrella plant
ERMA1	maculatum	
ERMA	marifolium	Mountain eriogonum
ERME3	mearnsii	
ERMO	monticola	
ERNI	nidularium	Birdsnest eriogonum
ERNI2	niveum	Snow eriogonum
ERNO	nodosum	Sonoran eriogonum
ERNU2	nudicaule	
ERNU	nudum	Barestem eriogonum
ERNU3	nummulare	
ERNU4	nutans	
EROC	ochrocephalum	Woolly eriogonum
EROS	ostlundii	
ERPA	parryi	
ERPH2	pharnaceoides	Wirestem eriogonum
ERPI	piperi	Piper eriogonum
ERPL	plumatella	[illegible] eriogonum
ERPU3	pusillum	
ERRA	racemosum	Redroot eriogonum
ERRA2	ramosissimum	
ERRE2	reniforme	Kidneyleaved eriogonum
ERRH	rhodanthum	
ERRO	rosense	
ERRU	rubricaule	Red wild buckwheat
ERSA	salicornioides	
ERSE	sessile	
ERSH	shockleyi	Shockley wild buckwheat
ERSI2	simpsonii	Simpson wild buckwheat

ERSP2	spathulatum	
ERSP3	sperculinum	
ERST	strictum	
ERSU5	subreniforme	
ERTE2	tenellum	Matted wild buckwheat
ERTH	thomasii	Thomas wild buckwheat
ERTH2	thymoides	Thyme eriogonum
ERTR2	trichopes	Little desert trumpet
ERUM	umbellatum (neglectum)	Sulfur eriogonum
ERVI	villiflorum	
ERVI2	viminium	Broom eriogonum
ERVI3	viridulum	
ERWA2	wahsatchense	
ERWE	wetherillii	
ERWR	wrightii	Wright eriogonum
ERZI	zionis	
ERIO3	Eriophyllum spp.	Eriophyllum
ERAM2	ambiguum	
ERLA	lanatum	Woolly eriophyllum
ERLA1	lanatum integrifolium	
ERPR	pringlei	
ERWA3	wallacei	Wallace eriophyllum
ERITR	Eritrichium spp	
ERNA4	nanum	
ERODI	Erodium spp.	Storksbill or Filaree
ERCI	cicutarium	Alfileria
ERTE3	texanum	Texas storksbill
ERUCA	Eruca spp	
ERSA2	sativa	Rocket salad
ERYNG	Eryngium spp	Eryngo
ERAL	alismaefolium	Inland eryngo
ERAR5	articulatum	Beethistle eryngo
ERYSI	Erysimum spp.	Wallflower
ERAR	argillosum	
ERAS	asperum	Plains erysimum
ERCH4	cheiranthoides	Treacle erysimum
ERIN5	inconspicuum (parviflorum)	Smallflower erysimum
ERNI3	nivale	Showy erysimum
ERRE3	repandum	Spreading erysimum

[illegible]	[illegible] spp.	[illegible] dogtooth violet
ERGR2	grandiflorum	Lambstongue fawnlily
ESCHS	Eschscholtzia spp	Goldpoppy
ESCA	californica	California poppy
ESGL	glyptosperma	Desert goldpoppy
ESME	mexicana	Mexican goldpoppy
ESMI	minutiflora	Little goldpoppy
EUCLI	Eucladium spp	
EUSY	syriacum	
EUCNI	Eucnide spp	Rocknettle
EUUR	urens	Stingbush
EUCRY	Eucrypta spp	
EUCH	chrysanthemifolia	
EUMI	micrantha	
EUPAT	Eupatorium spp	Eupatorium
EUHE	herbaceum	White thoroughwort
EUMA	maculatum	Spotted joe-pye-weed
EUOC	occidentale	Western eupatorium
EUPHO	Euphorbia spp	Euphorbia
EUAL	albomarginata	Whitemargin euphorbia
EUAR	arizonica	
EUCR	crenulata	Beetle euphorbia
EUCY	cyparissias	Cypress euphorbia
EUDE	dentata	Toothed euphorbia
EUES	esula	Leafy euphorbia
EUFE	fendleri	Fendler euphorbia
EUGL	glyptosperma	Ridgeseed euphorbia
EUIN	incisa	
EULA	lathyris	Caper euphorbia
EULU	lurida	Shiny euphorbia
EUMI2	micromera	Littleleaf euphorbia
EUNE	nephradenia	
EUO	ocellata	
EUPA2	palmeri	Palmer euphorbia
EUPA	parryi	
EUPH	philorus	
EUPO	polycarpa	
EUPO2	polygona	Polygon euphorbia
EURO	robusta	Robust euphorbia
EUSE	serpyllifolia	Thymeleaf euphorbia
EUSE2	setiloba	Yuma euphorbia
EUSP	spathulata	

FAGON	Fagonia spp.	Fagonia
FACA	californica	California fagonia
FILAG	Filago spp.	Fluffweed
FICA2	californica	California fluffweed
FLAVE	Flaveria spp.	
FLCA	campestris	
FLOER	Floerkea spp.	False mermaid
FLPR	proserpinacoides	False mermaid
FOENI	Foeniculum spp.	Fennel
FOVU	vulgare	Common fennel
FRAGA	Fragaria spp.	Strawberry
FRVE	vesca	European strawberry
FRVI	virginiana	Virginia strawberry
FRANS	Franseria spp.	(see Ambrosia)
FRASE	Frasera spp.	Frasera or elkweed
FRAL2	albicaulis	
FRAL	albomarginata	Whitemargin frasera
FRMO2	montana	Small frasera
FRPA	paniculata	
FRPU2	puberulenta	
FRSP	speciosa	Showy frasera
FRITI	Fritillaria spp.	Fritillary
FRAT	atropurpurea	Purplespot fritillary
FRPI	pinetorum	Pinewoods fritillary
FRPU	pudica	Yellow fritillary
FRRE	recurva	Scarlet fritillary
FUMAR	Fumaria spp.	Fumitory
FUOF	officinalis	Drug fumitory
GAILL	Gaillardia spp.	Gaillardia; blanketflower
GAAR	aristata	Common perennial gaillardia
GAAR2	arizonica	
GAFL	flava	
GAME	mearnsii	
GAMU2	multiceps	
GAPA	parryi	
GAPI	pinnatifida	Blanket flower
GASP	spathulata	

GALEG	Galega spp.	Goat rue
GAOF	officinalis	Common goatsrue
GALIN	Galinsoga spp.	Quickweed
GAPA2	parviflora	Little flower quickweed
GALIU	Galium spp.	Bedstraw
GAAPA	aparine aparine	Catchweed bedstraw
GAAPE	aparine echinospermum	
GABI	bifolium	Twinleaf bedstraw
GABO	boreale	Northern bedstraw
GACO2	coloradoense	
GAGR	grayanum	
GAHY	hypotrichium	
GAMA	magnifolium	
GAME2	mexicanum (asperrimum	Rough bedstraw
GAMU	multiflorum	Shrubby bedstraw
GAMU3	munzii	Munz bedstraw
GAPA3	parishii	Parish bedstraw
GAPR	proliferum	
GARO	rothrockii	Rothrock bedstraw
GARU	rubiodes	
GASE	serpenticum	
GAST	stellatum	
GATR	trifidum	Small bedstraw
GATR2	triflorum	Sweetscented bedstraw
GAWA	watsonii	
GAURA	Gaura spp.	Gaura
GACO	coccinea	Scarlet gaura
GAPA4	parviflora	Small flower
GAYOP	Gayophytum spp.	Groundsmoke
GAHU	humile	
GANU	nuttallii (diffusum)	Bigflower groundsmoke
GARA2	racemosum (caesium)	Branchy groundsmoke
GARA	ramosissimum	
GENTI	Gentiana spp.	Gentian
GEAF	affinis	Rocky Mountain pleated gentian
GEAL	algida	
GEAMH	amarella heterosepala	Annual gentian
GEBA	barbellata	
GECA	calycosa	Rainier pleated gentian

FORBS

GENTI	Gentiana spp. (con.)	
GEDE	detonsa	
GEFR2	fremontii	
GEHO	holopetala	
GENE	newberryi	Newberry gentian
GEOR	oregana	Oregon gentian
GEPA	parryi	Parry gentian
GEPR	prostrata	
GESI	simplex	
GETE	tennella	
GERAE	Geraea spp.	Desertgold
GECA	canescens	
GERAN	Geranium spp.	Geranium
GEBI	bricknellii	Bricknell
GECA3	caespitosum	Purple geranium
GECA4	caroliniana	Carolina geranium
GEFR	fremontii	Fremont geranium
GEMA2	marginale	
GENE2	nervosum	
GEPA2	parryi	Parry geranium
GEPR2	pratense	Meadow geranium
GEPU	pusillum	Small geranium
GERI	richardsonii	Richardson geranium
GESA	sanguineum	Bloodred geranium
GETUM	tuberosum macrostylum	
GEVIN	viscosissimum nervosum	Sticky geranium
GEVIV	viscosissimum viscosissimum	
GEUM	Geum spp.	Avens
GEAL2	aleppicum	Aleppo avens
GEMA	macrophyllum	Largeleaf avens
GERO	rossii	Golden avens
GETR	triflorum	
GILIA	Gilia spp. (see Ipomopsis)	Gilia
GIAL	aliquanta	
GIAU	austrooccidentalis	
GIBR	brecciarum	
GICA5	caespitosa	
GICA	calcarea	Sticky gilia
GICA2	campanulata	
GICA3	cana	
GICA4	capillaris	Hairstem gilia
GICL	clokeyi	

FORBS

GILIA	Gilia spp. (con.)	
GIDE	depressa	
GIFI	filiformis	
GIGA	galioides	
GIGU	gunnisonii	
GIHU	hutchinifolia	
GIIN	inconspicua	Shy gilia
GIIN2	interior	
GIIN3	inyoensis	
GILA	latifolia	
GILE	leptantha	
GILE2	leptomeria	
GILO	longiflora	
GIMC	mcvickerae	
GIMO	modocensis	
GIMU	multiflora	
GIOP	opthalmoides	
GIPO	polyantha	
GIPO2	polycladon	
GIPU	pumila	Dwarf gilia
GIRI	ripleyi	
GIRO	roseata	
GISC	scopulorum	
GISIT	sinuata tweedyi	
GISP	spicata	Spike gilia
GIST	stellata	
GISU	subnuda	
GITE	tenerrima	
GITE2	tenuituba	
GITR	transmontana	
GIVI	violaceum	
GLAUC	Glaucocarpum spp.	
GLSU	suffrutescens	
GLAUX	Glaux spp.	Saltwort; sea milkwort
GLMA	maritima	Sea milkwort
GLYCY	Glycyrrhiza spp.	Licorice
GLGL	glabra	Common licorice
GLLE	lepidota	American licorice
GLYPT	Glyptopleura spp.	
GLMA2	marginata	
GLSE	setulosa	
GNAPH	Gnaphalium spp.	Cudweed; everlasting
GNCH	chilense	Cottonbatting cudweed

GNAPH	Gnaphalium spp. cont.	
GNGR	grayi	
GNMA	macounii	Macoun cudweed
GNPA	palustre	
GOODY	Goodyera spp.	Rattlesnake plantain
GOOB	oblongifolia	Western rattlesnake plantain
GORE	repens	Creeping rattlesnake plantain
GRATI	Gratiola spp.	Hedge-hyssop
GREB	ebracteata	
GRNE	neglecta	
GRIND	Grindelia spp.	Gumweed; bumplant, resinweed
GRAP	aphanactis	
GRCA	camporum	Field gumweed
GRFA	fastigiata	
GRLA	laciniata	
GRNA	nana	Low gumweed
GRSQ	squarrosa	Curlycup gumweed
GYMNO	Gymnocarpium spp.	Oak fern
GYDR	dryopteris	Oak fern
GYMN3	Gymnosteris spp.	
GYNU	nudicaulis	
GYPA	parvula	
GYPSO	Gypsophila spp.	Gypsophila
GYPA2	paniculata	Babysbreath
GYPE	perfoliata	Clasping
HABEN	Habenaria spp.	Habenaria, rain orchid, bog-orchid
HADID	dilatata dilatata	White bog-orchid
HADIL	dilatata leucostachys	Milkwhite habenaria
HAOB	obtusata	
HASA	saccata	Modoc habenaria
HASP	sparsiflora	Canyon habenaria
HAUN	unalascensis	Alaska habenaria
HAVI	viridis	Satyr habenaria

HACKE	Hackelia spp.	Stickseed, wild forget me not
HACI	cinerea	
HACU	cusickii	
HADI2	diffusa	Spreading stickseed
HAFL	floribunda	Showy stickseed
HAJE	jessicae	Jessicae stickseed
HAPA	patens	
HALI2	Halimolobos spp	Halimolobos
HADI3	diffusa	
HAPEP	perplexa perplexa	Puzzling halimolobos
HAPEL	perplexa lemhiensis	
HAVI2	virgata	
HALOG	Halogeton spp.	Halogeton
HAGL	glomeratus	Halogeton
HAPLO	Haplopappus spp. (Aplopappus)	Goldenweed
HAAB	aberrans	
HAAC	acaulis	Stemless goldenweed
HAAP	apargioides	
HAAR	armerioides	Thrifty goldenweed
HACA	carthamoides	
HACL	clementis	
HACO	contractus	
HACO2	cooperi	Cooper goldenweed
HACR	croceus	
HADR	drummondii	Drummond goldenweed
HAGR	gracilis	Slender goldenweed
HAGR2	greenei	Greenes goldenweed
HAHI	hirtus	
HAIN	insecticruris	Wholeleaf goldenweed
HALA	lanceolatus	Lanceleaf goldenweed
HALA2	lanuginosus	
HALY	lyallii	
HANU	nuttallii	
HAPA2	parryi	
HAPY	pygmaeus	
HASP2	spinulosus	Ironplant goldenweed
HAST	stenophyllus	
HAUN2	uniflorus	Plantain goldenweed
HARBO	Harbouria spp.	
HATR	trachypleura	
HECAS	Hecastocleis spp.	
HESH	shockleyi	

HENA	nanum	
HEDYS	Hedysarum spp.	Sweetvetch
HEBO	boreale (cinerascens)	Northern sweetvetch
HEBO2	boreale germinale	Utah sweetvetch
HECO	coronarium	Sulla sweetvetch
HEGR	gremiale	
HEOC	occidentale	Western sweetvetch
HESU	sulphurescens	Sulfur sweetvetch
HELEN	Helenium spp	Sneezeweed
HEAU	autumnale	Common sneezeweed
HEBI	bigelovii	Bigelow sneezeweed
HEHO	hoopesii	Orange sneezeweed
HELIA	Helianthella spp.	Helianthella
HECA	californica	California helianthella
HEMI	microcephala	
HEQU	quinquenervis	Fivenerve helianthella
HEUN	uniflora	Oneflower helianthella
HELI2	Helianthus spp.	Sunflower
HEAN	annuus	Common sunflower
HEAN2	anomalus	
HECU	cusickii	
HEDE	deserticolus	
HEGR5	grosseserratus	Sawtooth sunflower
HEMA	maximilianus	Maximilian sunflower
HENU	nuttallii	
HEPE	petiolaris	Prairie sunflower
HELIO	Heliotropium spp	Heliotrope
HECO2	convolvulaceum	Bindweed heliotrope
HECU2	curassavicum	Salt heliotrope
HERAC	Heracleum spp	Cowparsnip
HELA	lanatum	Common cowparsnip
HERMI	Hermidium spp.	
HEAL	alipes	

	spp.	
HECA2	californicus	
HEPU	pumilus	
HETER	Heterocodon spp.	
HERA	rariflorum	
HETE2	Heterotheca spp. (chrysopsis)	Goldaster
HEBR	breweri	Brewer goldaster
HEFO	foliosa	Leafy goldaster
HEJO	jonesii	
HEVI	villosa	Hairy goldaster
HEUCH	Heuchera spp.	Alumroot
HECY	cylindrica (ovalifolia	Roundleaf alumroot
HEDU	duranii	
HEGR2	grossulariifolia	
HEPA	parvifolia	Littleleaf alumroot
HERU	rubescens	Red alumroot
HEVE	versicolor	Painted alumroot
HIBIS	Hibiscus spp.	Rosemallow
HITR	trionum	Flower-of-an-hour
HIERA	Hieracium spp.	Hawkweed
HIAL	albiflorum	White hawkweed
HICY	cynoglossoides	Houndstongue hawkweed
HITE	teneleri	
HIGR	gracile	Slender hawkweed
HISC	scouleri	Woollyweed
HIPPO	Hippocrepis spp.	
HICO	comosa	
HIGL	glauca	
HIMU	multisiliquosa	
HIPPU	Hippuris spp.	Marestail
HIVU	vulgaris	Marestail
HOFFM	Hoffmanseggia spp	Rushpea
HORE	repens	
HOFME	Hofmeisteria spp.	
HOPL	pluriseta	Bush arrowleaf
HOLOS	Holosteum spp.	
HOUM	umbellatum	
HORKE	Horkelia spp.	Horkelia
HOFU	fusca	Tawny horkelia
HOHI	hispidula	

HULSE	Hulsea spp	
HUAL	algida	
HUHE	heterochroma	
HUVE	vestita	
HUMUL	Humulus spp	Hop
HUAM	americanus	American hop
HULU	lupulus	Common hop
HUTCH	Hutchinsia p	
HUPR	procumbens	
HYDRO	Hydrocotyle spp.	Pennywort
HYVE	verticillata	Whorled pennywort
HYDRO2	Hydrophyllum spp	Waterleaf
HYCA	capitatum	Ballhead waterleaf
HYFE	fendleri	Fendler waterleaf
HYOC	occidentale	Western waterleaf
HYME2	Hymenopappus	Hymenopappus
HYFIF	filifolius filifolius	Fineleaf hymenopappus
HYFIC	filifolius cinerus	
HYFIE	filifolius eriopodas	
HYFII	filifolius idahoensis	
HYME3	Hymenoxys spp	Hymenoxys
HYAC	acaulis	Stemless hymenoxys
HYCO	cooperi	
HYGR	grandiflora	Graylocks hymenoxys
HYHE	helenioides	
HYIV	ivesiana	
HYLE	lemmonii	
HYRI	richardsonii	Pingue hymenoxys
HYSC	scaposa	
HYSU	subintegra	
HYTO	torreyana	
HYOSC	Hyoscyamus spp	Henbane
HYNI	niger	Black henbane
HYPER	Hypericum spp	St. Johns wort
HYAN	anagalloides	Trailing St. Johns-wort
HYFO	formosum	Southwestern St. Johns wort
HYPE	performatum	Klamath weed
HYFOS	scouleri	Scouler St. Johns wort
HYSSO	Hyssopus spp	Hyssop
HYOFA	**officinalis**	

IDAHO	Idahoa spp	
IDSC	scapigera	
ILIAM	Iliamna spp	
ILGR	grandiflora	Wild hollyhock
ILRIR	rivularis rivularis	Stream iliamna
ILRID	rivularis diversa	
INULA	Inula spp.	Inula
INHE	helenium	Elecampane inula
IPOMP	Ipomopsis spp. (Gilia)	
IPAG	aggregata	Skyrocket gilia
IPCO	congesta	Ballhead gilia
IRIS	Iris spp.	Iris
IREN	ensata	Russian iris
IRGE	germanica	German iris
IRMI	missouriensis	Rocky Mountain iris
ISATI	Isatis spp.	Woad
ISTI	tinctoria	Dyers woad
ISOET	Isoetes spp.	Quillwort
ISBO	bolanderi	Bolander quillwort
ISHO	howellii	Howell quillwort
ISME	melanopoda	Blackfoot quillwort
ISNU	nuttallii	Nuttall quillwort
ISOC	occidentalis	
IVA	Iva spp	Sumpweed
IVAX	axillaris	Poverty sumpweed
IVNE	nevadensis	
IVXA	xanthifolia	Rag sumpweed
IVESI	Ivesia spp.	Ivesia
IVBA	baileyi	
IVGO	gordonii	Gordon ivesia
IVKI	kingii	
IVLY	lycopoidoides	
IVPU	purpurascens	
IVSA	sabulosa	
IVUT	utahensis	Utah ivesia
IVWE	webberi	
KELLO	Kelloggia spp	
KEGA	galioides	
KELSE	Kelseya spp	Kelseya
KEUN	uniflora	

KOCHI	Kochia spp	Summer cypress
		summer cypress
KOIN	indica	
KOIR	iranica	
KOSP	scoparia	Belvedere summer cypress
KUHNI	Kuhnia spp	False boneset
KUEU	eupatoroides	
LACTU	Lactuca spp	Lettuce
LACA	canadensis	Canada lettuce
LAPU	pulchella	Chicory lettuce
LASE	serriola integrata	Prickly lettuce
LAGOP	Lagophylla spp	
LARA	ramosissima	
LAMIU	Lamium spp	Deadnettle
LAAM	amplexicaule	Henbit deadnettle
LAPU2	purpureum	Purple deadnettle
LANGL	Langloisia spp	
LAMA	matthewsii	
LAPU3	punctata	
LASC	schottii	
LASE2	setosissima	
LAPPU	Lappula spp	Stickseed
LAEC	echinata	European stickseed
LAOC	occidentalis redowskii	Annual stickseed
LATHY	Lathyrus spp	Peavine
LAAR	arizonicus	Arizona peavine
LABI	bijugatus	Drypark peavine
LABR	brachycalyx	
LAEU	eucosmus	Bush peavine
LALA	lanszwertii	Thickleaf peavine
LALA2	latifolius	Perennial peavine
LALE	leucanthus	Aspen peavine
LANE	nevadensis	Nevada peavine
LAOD	odoratus	Sweetpea
LAPA	pauciflorus	Fewflower peavine
LARI	rigidus	
LASY	sylvestris	Flat peavine
LAUT	utahensis	Utah peavine
LAYIA	Layia spp	Tidytips
LAGL	glandulosa	Whitedaisy tidytips
LEMNA	Lemna spp	Duckweed
LEGI	gibba	Swollen duckweed
LEMI	minima	Least duckweed
LEMI2	minor	Common duckweed
LETR	trisulca	Star duckweed
LEVA	valdiviana	
LEONU	Leonurus spp	Motherwort
LECA	cardiaca	Common motherwort
LECA	campestre	Field pepperweed
LEDA	davisii	
LEDED	densiflorum densiflorum	Prairie pepperweed
LEDEP	densiflorum pubicarpum	
LEDI	dictyotum	
LEFL	flavum	
LEFR	fremontii	Desert pepperweed
LELA2	lasiocarpum	
LEMOM	montanum montanum	Mountain pepperweed
LEMOP	montanum papilliferum	
LENA	nanum	
LEPE	perfoliatum	Clasping pepperweed
LEPU2	pubescens	
LEVI	virginicum	Virginia pepperweed
LESPE	Lespedeza spp.	Lespedeza
LECU	cuneata	Chinese lespedeza
LEPE2	pendiliflora	
LEST	stipulacea	Korean lespedeza
LESQU	Lesquerella spp.	Bladderpod
LEAL	alpina	Alpine bladderpod
LEAR	arizonica	Arizona bladderpod
LEBA	barnebyi	
LECA4	calcicola	
LECA	carinata	Keeled bladderpod
LECI	cinerea	
LECO	condensata	
LEFE	fendleri	Fendler bladderpod
LEGA	garrettii	
LEGO	gordonii	Gordon bladderpod
LEHE	hemiphysaria	
LEHI	hitchcockii	Hitchcock bladderpod
LEIN	intermedia	
LEKI	kingii	King bladderpod
LELA3	latifolia	
LELU	ludoviciana	Silver bladderpod
LEMA	macrocarpa	
LEMU	multiceps	
LEOC	occidentalis	
LEPA2	paysonii	
LEPR	prostrata	
LERE2	rectipes	
LERU	rubicundula	
LESH	sherwoodii	

FORBS

LESQU	Lesquerella spp. (con.)	
LESU	subumbellata	
LETE	tenella	
LETU	tumulosa	
LEUT	utahensis	
LEWA2	wardii	Ward bladderpod
LEUC	Leucelene spp.	Aster
LEER	ericoides	Heath aster
LEUCO	Leucocrinum spp.	Starlily
LEMO2	montanum	Common starlily
LEWIS	Lewisia spp.	Lewisia
LEBR	brachycalyx	
LECO	columbiana	Columbia lewisia
LEKE	kelloggii	Kellogg lewisia
LEMA	maguirei	
LEPYP	pygmaea pygmaea	Least lewisia
LEPYN	pygmaea nevadensis	Nevada lewisia
LERE	rediviva	Bitterroot lewisia
LETR	triphylla	Threeleaf lewisia
LIATR	Liatris spp.	Gayfeather
LIPU3	punctata	Dotted gayfeather
LIGUS	Ligusticum spp.	Ligusticum or lovage
LIAM	amurense	
LICA	canbyi	
LIFIF	filicinum filicinum	Fernleaf ligusticum
LIGR	grayi	Grays ligusticum
LIPO	porteri	Porter ligusticum
LITE	tenuifolium	Slender leafed ligusticum
LILAE	Lilaea spp.	Lilaea
LISC	scilloides	Awlleaf lilaea
LILIU	Lilium spp.	Lily
LICO	columbianum	Columbia lily
LIPA3	parvum	Sierra lily
LIUM	umbellatum	Western orange cup lily
LIMOS	Limosella spp.	Mudwort
LIAQ	aquatica	Water mudwort
LINAN	Linanthastrum spp.	
LIME	melingii	
LINU	nuttallii	Nuttall gilia

FORBS

LINAN2	Linanthus spp.	
LIAR2	arenicola	
LIAU	aureus	Yellow gilia
LIBI	bigelovii	Painted trumpet
LICI	ciliatus	
LIDE2	demissus	Bell trumpet
LIDI	dichotomus	Evening snow gilia
LIHA	harknessii	Harkness gilia
LIPA2	parryae	
LIPH	pharnaceoides	
LISE	septentrionalis	
LINAR	Linaria spp.	Toadflax
LIDA	dalmatica	Dalmatian toadflax
LIGE	genistifolia	Broomleaf toadflax
LIVU	vulgaris	Butter-and-eggs toadflax
LINDE	Lindernia spp.	False pimpernel
LIAN	anagallidea	
LIDU	dubia	
LINNA	Linnaea spp.	Twinflower
LIBO	borealis	Longtube twinflower
LINUM	Linum spp.	Flax
LIAR	aristatum	
LIKI	kingii	King flax
LILE2	leptopoda	
LILE	lewisii	Lewis flax
LIMI	micranthum	
LIRI	rigidum	Stiffstem flax
LIUS	usitatissimum	Common flax
LISTE	Listera spp.	Listera
LIBO2	borealis	
LICA2	caurina	Northwestern listera
LICO	convallarioides	
LICO3	cordata	Northern listera
LITHO	Lithophragma spp.	Woodlandstar
LIBU	bulbifera	
LIGL	glabra	
LIPA	parviflora	Smallflower woodlandstar
LIRU	rupicola	
LITE	tenella	Slender woodlandstar

LIAR3	arvense	Corn gromwell
LIIN	incisum	Narrowleaf gromwell
LIMU	multiflorum	Manyflower gromwell
LIOF	officinale	
LIRU	ruderale	Wayside gromwell
LLOYD	Lloydia spp.	Alplily
LLSE	serotina	Common alplily
LOBEL	Lobelia spp.	Lobelia
LOCA	cardinalis	Cardinalflower
LOEFL	Loeflingia spp.	
LOSQ	squarrosa	
LOMAT	Lomatium spp.	Desert parsley, biscuitroot, lomatium
LOAM	ambiguum	Wyeth biscuitroot
LOBI	bicolor	Wasatch [illegible]
LOCA2	canbyi	Canby biscuitroot
LOCI	circumdatum	Wallowa [illegible]
LOCO	cous	Cous biscuitroot
LODI	dissectum	[illegible]rnleaf leptotaenia
LODO	donnellii	Donnell biscuitroot
LOGR	grayi	Gray lomatium
LOHE	hendersonii	Henderson lomatium
LOID	idahoense	
LOJU	juniperinum	Juniper lomatium
LOLA	latilobum	
LOLE	leptocarpum	Bicolor [illegible]
LOMA	macdougalii	MacDougal lomatium
LOMA3	macrocarpum	Bigseed lomatium
LOME	megarrhizum	
LOMI	minimum	
LOMO	mohavense	Mohave lomatium
LOMO3	montanum	
LONE	nevadense	Nevada lomatium
LONU2	nudicaule	Barestem lomatium
LONU	nuttallii	Nuttall lomatium
LOOR	orientale	Oriental lomatium
LOPA	parryi	Parry lomatium
LOPL	plummerae	Plummer lomatium
LORA	ravenii	Raven lomatium
LOSC	scabrum	Rough lomatium
LOTRT	triternatum triternatum (simplex)	Narrowleaf lomatium
LOTRP	triternatum platycarpum	Nineleaf lomatium
LOTUS	Lotus spp.	Deervetch
LOAR2	arenarius	
		deervetch
LOCR	crassifolius	Big deervetch
LOHU	humistratus	Foothill deervetch
LOLO	longebracteatus	Longbract deervetch
LOME2	mearnsii	Mearns deervetch
LONE2	nevadensis	Nevada deervetch
LOOB	oblongifolius	Stream deervetch
LOPI	pinnatus	Meadow deervetch
LOPU	purshianus	Pursh deervetch
LORI2	rigidus	Shrubby deervetch
LOSA	salsuginosus	
LOTO	tomentellus	Desert deervetch
LOUT2	utahensis	Utah deervetch
LOWR	wrightii	Wright deervetch
LUDWI	Ludwigia spp.	Seedbox
LUPA4	palustris	
LUPIN	Lupinus spp.	Lupine
LUAL	alpestris	Mountain lupine
LUAM	ammophilus	Sand lupine
LUAN	andersonii	Anderson lupine
LUARC	arbustus calcaratus	
LUAR	argenteus (spathulatus)	Silvery lupine
LUAR2	arizonicus	Arizona lupine
LUBA	barbiger	
LUBR	brevicaulis	Shortstem lupine
LUCA	caudatus	Tailcup lupine
LUCO	concinnus	Bajada lupine
LUDU	duranii	Inyo lupine
LUFL	flavoculatus	
LUFU	fulcratus	
LUGR	grayi	Grays lupine
LUHO	holmgrenanus	Holmgren lupine
LUHO2	holosericeus	
LUIN	inyoensis	
LUKI	kingii	Kings lupine
LULA	latifolius	Broadleaf lupine
[illegible]	lepidus	Pacific lupine
LULE	leucophyllus	Velvet lupine
LUMA	malacophyllus	
LUME	meionanthus	Tahoe lupine
LUMO	montigenus	
[illegible]	nanus	Sky lupine
LUNE	nevadensis	Nevada lupine
LUOD	odoratus	Mohave lupine
LUON	onustus	[illegible]ound lupine
LUOS	osterhoutianus	Osterhout lupine
LUPA	pachylobus	Bigpod lupine
LUPA3	palmeri	Palmer lupine

FORBS

LUPIN	Lupinus spp.	con.
LUPO	polyphyllus	Washington lupine
LUPU	pusillus	Rusty lupine
LURU	rubens	Yelloweye lupine
LUSA	saxosus	Rock lupine
LUSE	sericeus	Silky lupine
LUSH	shockleyi	Desert lupine
LUSP	sparsiflorus	Coulter lupine
LUSU	subvexu	
LUUN	unicialis	
LUWY	wyethii	
LYCHN	Lychnis spp	Campion
LYAL	alba	Evening campion
LYAP	apetala	
LYCO	coronaria	Rose campion
LYDRD	drummondii drummondii	Drummond campion
LYDRS	drummondii striata	
LYKI	kingii	Kings campion
LYCOP	Lycopus spp	Bugleweed
LYAM	americanus bugleweed	American bugleweed
LYAS	asper	Rough bugleweed
LYGOD	Lygodesmia spp.	Skeletonplant, skeletonweed
LYEX	exigua	
LYGR	grandiflora	
LYJU	juncea	Rush skeletonplant
LYSP	spinosa	Thorn skeletonplant
LYSIM	Lysimachia spp. (Steironema)	Loosestrife
LYCI	ciliatum	Fringed loosestrife
LYLA	lanceolatum	
LYTH	thyrsiflora	Water loosestrife
LYTHR	Lythrum spp.	Lythrum
LYCA	californicum	
LYRO	roseum	
LYSA	salicaria	Purple lythrum
MACHA	Machaeranthera spp.	Aster
MABI	bigelovii	Bigelow aster
MACA	canescens	Hoary aster
MACO	commixta	
MAGL2	glabriuscula	Alkali aster
MAGRG	grindelioides grindelioides	
MAGRD	grindelioides depressa	
MAKI	kingii	
MALA	laetevirens	
MALE		

FORBS

MACHA	Machaeranthera spp.	con.
MALI	linearis	
MAMU	mucronata	
MAPA	parviflora	
MASH	shastensis	
MATA	tenacetifolia	Tansyleaf aster
MATE	tephrodes	
MATO	tortifolia	Mohave aster
MAVE	venusta	
MACH2	Machaerocarpus spp.	Damasonium
MACA2	californicus	California damasonium
MADIA	Madia spp.	Tarweed
MAEX	exigua	
MAGL	glomerata	Cluster tarweed
MAGR	gracilis	
MALAC	Malacothrix spp.	Desert dandelion
MACO2	coulteri	Snakes head
MAGL3	glabrata	Desert-dandelion
MASO	sonchoides	Sowthistle malacothrix
MATO2	torreyi	
MALAX	Malaxis spp.	Addermouth orchid
MABR	brachypoda	Sheath addermouth orchid
MALCO	Malcolmia spp.	Mustard
MAAF	africana	African mustard
MALVA	Malva spp.	Mallow
MANE	neglecta (rotundifolia)	Running mallow
MALV2	Malvastrum spp.	False mallow
MAEX2	exile	
MARO	rotundifolium	Running mallow
MAMMI	Mammillaria spp. (Coryphantha)	mammillaria
MAMI	microcarpa	Fishhook mammillaria
MATE2	tetrancistra	
MARRU	Marrubium spp	Horehound
MAVU	vulgare	Common horehound
MARSI	Marsilea spp.	Pepperwort
MAMU2	mucronata	
MATRI	Matricaria spp.	Mayweed
MAMA	matricarioides	Pineappleweed

MAURA	Maurandia spp.	Maurandia
MAAN	antirrhiniflora	
MEDIC	Medicago spp.	Medick, alfalfa
MEFA	falcatus	Sickle alfalfa
MEGL	glomerata	
MEGL2	glutinosa	
MEHI	hispida	California burclover
MELU	lupulina	Black medick
MEMI	minima	Little medick
MEOR	orbicularis	Button medick
MEPL	platycarpa	
MEPO	polymorpha	
MESA	sativa	Alfalfa
MESA1	sativa ladak	Ladak alfalfa
MESAN	sativa nomad	Nomad alfalfa
MESAR	sativa rambler	Rambler alfalfa
MESO	sogdiana	
METI	tianschanica	
METU	turbinata	
MELIL	Melilotus spp.	Sweetclover
MEAL	alba	White sweetclover
MEIN	indica	Annual yellow sweetclover
MEOF	officinalis	Yellow sweetclover
MESU	sulcata	
MELIS	Melissa spp	Balm
MEOF2	officinalis	Common balm
MENTH	Mentha spp.	Mint
MEAR	arvensis canadensis)	Field mint
MEPI	piperita	Peppermint
MESP3	spicata	Spearmint
MENT2	Mentzelia spp.	Mentzelia
MEAL2	albicaulis	Whitestem mentzelia
MEAR2	argillosa	
MECH	chrysantha	
MECO	congesta	
MECR	cronquistii	
MEDE	decapetala	Tenpetal mentzelia
MEDI	dispersa	Bushy mentzelia
MEHU	humilis	
MELA2	laevicaulis	Blazingstar mentzelia
MELE	leucophylla	
MEMO	mollis	
MEMO2	montana	
MEMU	multiflora	Desert mentzelia
MENI	nitens	

MENT2	Mentzelia spp	(con.)
MEPO3	polita	
MEPT	pterosperma	
MEPU	pumila	Golden blazingstar
MERU	rusbyi	
METO	torreyi	
METR	tricuspis	
MEVE	veatchiana	
MENYA	Menyanthes spp.	Bogbean
METR2	trifoliata	Common bogbean
MERTE	Mertensia spp.	Bluebells
MEAR3	arizonica leonardi	Tall bluebells
MEBR	brevistyla	Shortstyle bluebells
MECA	campanulata	Idaho bluebells
MECI	ciliata	Mountain bluebells
MEFR2	franciscana	Franciscan bluebells
MEFU2	fusiformis	Spindleroot bluebells
MELA	lanceolata	Lanceleaf bluebells
MELO	longiflora	Small bluebells
MEMA	macdougalii	
MEOB	oblongifolia	Oblongleaf bluebells
MEPA	paniculata	Panicle bluebells
METO2	toiyabensis	
MEVI	viridis (amoena)	Greenleaf bluebells
MEVI2	viridis (foliosa)	Greenleaf bluebells
MICRO	Microseris spp	Microseris
MILI	lindleyi	
MINI	nigrescens	
MINU	nutans	Nodding microseris
MICR2	Microsteris spp.	
MIGR	gracilis	
MIMUL	Mimulus spp	Monkeyflower
MIAU	austinae	
MIBI	bigelovii	
MIBR	brachystylis	
MIBR2	breviflorus	

FORBS

MIMUL	Mimulus spp.	cont.
MIBR3	breweri	Brewer monkeyflower
MICA	cardinalis	Crimson monkeyflower
MICO	coccineus	
MICU	cusickii	
MIDE	densus	
MIEA	eastwoodiae	
MIFL	floribundus	Purplestem monkeyflower
MIGLF	glabratus fremontii	
MIGLU	glabratus utahensis	
MIGU	guttatus	Common monkeyflower
MILE2	leptanthus	Slender monkeyflower
MILE	lewisii	Lewis monkeyflower
MIMO	moschatus	Muskplant monkeyflower
MINA	nanus	Dwarf monkeyflower
MIPA	parryi	
MIPI	pilosus	
MIPR	primuloides	Primrose monkeyflower
MIRE	reifschneiderae	
MIRU	rubellus	
MISP	spissus	
MISU	suksdorfii	
MITI	tilingi	
MITO	torreyi	
MIWA	washingtonensis	
MIRAB	Mirabilis spp.	Four o'clock
MIBIB	bigelovii bigelovii	Bigelow four o'clock
MIBIR	bigelovii retrorsa	Wishbone plant
MIFR	froebelii	
MIJA	jalapa	Prairie four-o'clock
MILA	laevis	
MIMU	multiflora	Colorado four-o'clock
MIOX	oxybaphoides	
MIPU	pudica	
MITEL	Mitella spp.	Miterwort
MICA2	caulescens	
MIPE	pentandra	Fivestamen miterwort
MIST2	stauropetala	
MIST	stenopetala	Smallflower miterwort
MOHAV	Mohavea spp.	Mohavea
MOBR	breviflora	
MOCO	confertiflora	
MOLDA	Modavica spp.	Dragonhead
MOPA	parviflora	American dragonhead

FORBS

MOLLU	Mollugo spp.	Carpetweed
MOVE	verticillatta	Carpetweed
MOLUC	Molucella spp.	Molucca-balm
MOLA	laevis	Asian Molucca-balm
MONAR	Monarda spp.	Beebalm
MOFI	fistulosa	Wildbergamot beebalm
MOPE	pectinata	Pony beebalm
MONA2	Monardella spp.	Monardella
MOLA2	lanceolata	
MOLI	linoides	Narrowleaf monardella
MOOD	odoratissima	Pacific monardella
MONOD	Monodora spp.	Monodora
MOME	methaefolia	
MOSC	scabra	Rough monodora
MOSP	spinescens	Spiny monodora
MONOL	Monolepis spp.	Monolepis
MONU	nuttalliana	Nuttall monolepis
MOPU	pusilla	
MOSP2	spathulata	
MONOP	Monoptilon spp.	
MOBE	bellioides	
MONTI	Montia spp.	Indian lettuce or Miners lettuce
MOAR	arenicola	
MOCH	chamissoi	Water montia
MOCO2	cordifolia	
MOHA	hallii	
MOLI2	linearis	Lineleaf miners lettuce
MOPA2	parviflora	Littleleaf montia
MOPE2	perfoliata	Miners lettuce
MOSI	sibirica	Siberian miners lettuce
MOSP3	spathulata	
MORTO	Mortonia spp.	Mortonia
MOUT	utahensis	Utah mortonia
MUILL	Muilla spp.	
MUTR	transmontana	
MUSIN	Musineon spp.	Musineon
MUDI	divaricatum	Leafy musineon
MULI	lineare	
MUTE	tenuifolium	

		forget-me-not
MYLA	laxa	Bay forget-me-not
MYSC	scorpioides	True forget-me-not
MYOSU	Myosurus spp.	Mousetail
MYAR	aristatus	
MYCU	cupulatus	
MYMI	minimus	Tiny mousetail
MYRIO	Myriophyllum spp.	Parrotfeather water milfoil
MYBR	brasiliense	Brazilian parrotfeather
MYHI	hippuroides	
MYSP	spicatum	
NAJAS	Najas spp.	Naiad
NAFL	flexilis	Slender naiad
NAGU	guadalupensis	Southern naiad
NAMA	mariani	Spiny naiad
NAMA2	Nama spp.	Nama
NAAR	aretioides	
NADE	demissum	Leafy nama
NADE2	densum	
NADE3	depressum	
NADI	dichotomum	
NARO	rothrockii	
NASTU	Nasturtium spp.	Watercress
NAOF	officinale	Watercress
NAVAR	Navarretia spp.	
NABR	breweri	Brewer gilia
NAIN	intertexta	Woolly navarretia
NALE	leucocephala	
NAMI	minima	
NEMAC	Nemacladus spp.	
NEGL	glanduliferus	
NEGR	gracilis	
NERI	rigidus	
NERU	rubescens	
NEMOP	Nemophila spp.	Nemophila
NEBR	breviflora	Great Basin nemophila
NEPA	parviflora	Smallflower nemophila
NEPE	pedunculata	
NESP	spatulata	
NEPET	Nepeta spp.	Nepeta
NECA	[illegible]	
NECA2	cataria	Catnip

NEIT	italica	
NEVE	veitchi	
NICOT	Nicotiana spp.	Tobacco
NIAT	attenuata	Coyote tobacco
NIPA	palmeri	
NITR	trigonophylla	Desert tobacco
NITRO	Nitrophila spp.	Niterwort
NIOC	occidentalis	
NOLIN	Nolina spp.	Nolina
NOBI	bigelovii	Bigelow nolina
NOTHO	Nothocalais spp.	
NOAL	alpestris	
NOTR	troximoides	
NOTH2	Notholaena spp.	Cloakfern
NOJO	jonesii	Jones cloakfern
NOLI	limitanea	
NOPA	parryi	Parry cloakfern
NOSI	sinuata	Bulb cloakfern
NOST	standleyi	Star cloakfern
NUPHA	Nuphar spp.	Cowlily, yellow pondlily
NUPO	polysepalum	Rocky Mountain cowlily
NYMPH	Nymphaea spp.	Waterlily
NYOD	odorata	American waterlily
OENOT	Oenothera spp. (see Camissonia)	Evening primrose
OEAL2	albicaulis	Prairie evening primrose
OEBI	biennis	Common evening primrose
OECA	caespitosa	Tufted evening primrose
OECA3	cavernae	
OECO	coronopifolia	
OEDE2	deltoides	
OEHO	hookeri	Hooker evening primrose
OELA2	latifolia	
OELA	lavandulaefolia	Lavenderleaf evening primrose
OELO	longissima	
OENU	nuttallii	Nuttall evening primrose
OEPAP	pallida pallida	Pale evening primrose
OEPAI	pallida idahoensis	
OEPR	primiverus	

FORBS

OENO1	Oenothera spp. (con.)	
OETR	trichocalyx	
OEXY	xylocarpa	
OLIGO	Oligomeris spp.	
OLLI	linifolia	
ONOBR	Onobrychis spp.	Sainfoin
ONGR	grandes	
ONTR	transcaucasica	
ONVI	viciaefolia (sativa)	Common sainfoin
ONONI	Ononis spp.	
ONSP	speciosa	
ONOPO	Onopordum spp.	Thistle
ONAC	acanthium	Scotch cottonthistle
ONYCH	Onychium spp.	Claw fern
ONDE	densum	Claw fern
OREOX	Oreoxis spp.	Oreoxis
ORAL	alpina	Alpine oreoxis
ORBA	bakeri	
ORNI1	Ornithogalum spp.	Star-of-Bethlehem
ORUM	umbellatum	Common star-of-Bethlehem
ORNI2	Ornithopus spp.	Serradella
ORCO	compressus	
OROBA	Orobanche spp.	Broomrape
ORCA	californica	
ORFA	fasciculata	
ORGR	grayana	
ORLU	ludoviciana	Louisiana broomrape
ORMU	multiflora	
ORUN	uniflora	Ghost-pipe
OROGE	Orogenia spp.	
ORLI	linearifolia	Indian potato
ORTHO	Orthocarpus spp.	Owlclover
ORBR	bracteosus	
ORCA2	campestris	
ORCO2	copelandii	
ORHI	hispidus	
ORLA	lacerus	
ORLU2	luteus	Yellow owlclover
ORPU	purpurascens	Escobita owlclover
ORPU2	purpureo albus	Purplewhite owlclover

FORBS

ORTHO	Orthocarpus spp. (con.)	
ORTE	tenuifolius	
ORTO	tolmiei	Tolmie owlclover
ORYCE	Oryctes spp.	
ORNE	nevadensis	
OSMOR	Osmorhiza spp.	Sweetroot
OSCH	chilensis (divaricata)	Spreading sweetroot
OSDE	depauperata (obtusa)	Bluntseed sweetroot
OSOC	occidentalis	Sweetanise
OXALI	Oxalis spp.	Oxalis, woodsorrel
OXCO	corniculata	Creeping oxalis
OXDI2	dillenii	
OXGR	grayii	
OXPI	pilosa	
OXST	stricta	Common yellow oxalis
OXYBA	Oxybaphus spp.	Umbrellawort
OXCO2	coccineus	Scarlet umbrellawort
OXCO3	comatus	Sticky umbrellawort
OXGL	glaber	
OXLI	linearis	Narrowleaf umbrellawort
OXNY	nyctagineus	
OXPU	pumilus	
OXYPO	Oxypolis spp.	Cowbane
OXFE	fendleri	Fendler cowbane
OXYRI	Oxyria spp.	Mountain sorrel
OXDI	digyna	Alpine mountain sorrel
OXYST	Oxystylis spp.	
OXLU	lutea	
OXYTE	Oxytenia spp.	Oxytenia
OXAC	acerosa	Prickly oxytenia
OXYTH	Oxytheca spp.	Oxytheca
OXDE	dendroidea	Narrowleaf oxytheca
OXLU2	luteola	
OXPE	perfoliata	Thoroughwort oxytheca
OXWA	watsonii	Watson oxytheca
OXYTR	Oxytropis spp.	Crazyweed
OXBEB	besseyi besseyi	Bessey pointvetch
OXBEA	besseyi argophylla	

[illegible]	Oxytropis spp.	[illegible]
OXBES	besseyi salmonensis	
OXCA	campestris	Plains crazyweed
OXDE2	deflexa	Droppod crazyweed
OXJO	jonesii	
OXLA	lambertii	Lambert crazyweed
OXMU	multiceps	Flowery crazyweed
OXOB	obnapiformis	
OXOR	oreophila	Silver crazyweed
OXPA	parryi	Parry crazyweed
OXSE	sericea	Silky crazyweed
OXVI	viscida	Yellowhair crazyweed
PAEON	Paeonia spp.	Peony
PABR	brownii	Browns peony
PALAF	Palafoxia spp.	Palafoxia
PALI	linearis	Desert palafoxia
PAPAV	Papaver spp.	Poppy
PARA	radicatum	
PARH	rhoea	Corn poppy
PARIE	Parieteria spp.	Pellitory
PAFL2	floridana	
PAPE	pennsylvanica	Pennsylvania pellitory
PARNA	Parnassia spp.	Parnassia parnassus
PAFI	fimbriata	Rocky Mountain parnassia
PAKO	kotzebuei	
PAPA2	palustris	Wildworld parnassia
PAPA3	parviflora	Smallflower parnassia
PARON	Paronychia spp.	Nailwort
PAPU	pulvinata	Rocky Mountain nailwort
PASE	sessiliflora	Creeping nailwort
PARRY	Parrya spp.	Parrya
PANU	nudicaulis	
PARY	rydbergii platycarpa	Utah parrya
PASTI	Pastinaca spp.	Parsnip
PASA	sativa	Garden parsnip

PECTI	Pectis spp.	Pectis
PEAN	angustifolia	
PEPA3	papposa	
PECTO	Pectocarya spp.	Combseed
PEHE	heterocarpa	
PEPE	penicillata	Shortleaf combseed
PEPL	platycarpa	
PERE	recurvata	
PESE	setosa	
PEDIC	Pedicularis spp.	Lousewort
PEAT	attollens	
PEBR	bracteosa	Bracted pedicularis
PECE	centranthera	Dwarf lousewort
PECO2	contorta	Coiled lousewort
PECR	crenulata	Meadow lousewort
PEGR2	grayi	Grays lousewort
PEGR	groenlandica	Elephanthead lousewort
PEPA4	parryi	Parry lousewort
PEPR	procera	
PERA3	racemosa	Sickletop pedicularis
PESE	semibarbata	
PEGAN	Peganum spp.	Peganum
PEHA	harmala	Harmel peganum
PELLA	pellaea spp.	Cliffbrake
PEAT2	atropurpurea	Purple cliffbrake
PEBR2	breweri	Brewer cliffbrake
PEBR3	bridgesii	Bridges cliffbrake
PEGL	glabella	Dwarf cliffbrake
PELO	longi-mucronat	Spiny cliffbrake
PENNE	Pennellia spp.	
PEMI	micrantha	
PENST	Penstemon spp.	Beardtongue, penstemon
PEAB	abietinus	Firleaf penstemon
PEAC	acaulis	Stemless penstemon
PEAC2	acuminatus	Sharpleaf penstemon
PEAL	albertinus	Alberta penstemon
PEAL2	albomarginatus	
PEAM	ambiguus	Gilia penstemon
PEAN	angustifolia	Narrowleaf penstemon
PEAR3	arenarius	Dune penstemon
PEAR2	arenicola	Sand penstemon
PEAR	aridus	Stiffleaf penstemon
PEAT3	attenuatus	Sulphur penstemon
PEAT4	atwoodii	

FORBS

PENST	Penstemon spp. (con.)	
PEBA	barbatus	Beardlip penstemon
PEBR4	bracteatus	
PEBR5	bridgesii	Bridges penstemon
PECA	caespitosus	Mat penstemon
PECA2	carnosus	
PECI	cinerascens	
PECI2	cinicola	
PECL	cleburnei	
PECO	comarrhenus	Dusty penstemon
PECO3	concinnus	
PECO4	confertus	Yellow penstemon
PECO5	confusus	
PECO6	congesta	
PECR	crandallii	Crandall penstemon
PECU	cusickii	Cusick penstemon
PECY	cyananthus	Wasatch penstemon
PECY2	cyaneus	
PECY3	cyanocaulis	
PEDA	davidsonii	Davidson penstemon
PEDE	deustus	Scabland penstemon
PEDI	digitalis	Digitalis penstemon
PEDO	dolius	Jones penstemon
PEEA	eatonii	Eaton penstemon
PEEL	ellipticus	Rockvine penstemon
PEER	eriantherus	Fuzzytongue penstemon
PEFL	floridus	Panamint penstemon
PEFR	fremontii v.glaber	Fremont penstemon
PEFR2	fruticiformis	Desert mountain penstemon
PEFR3	fruticosus	Bush penstemon
PEGA3	gairdneri	Gairdner penstemon
PEGA2	garrettii	Garretts penstemon
PEGL2	glaber	Sawsepal penstemon
PEGL3	glandulosus	Stickystem penstemon
PEGR3	gracilentus	Slimstem penstemon
PEGR4	grahamii	Graham penstemon
PEHA2	hallii	Halls penstemon

FORBS

PENST	Penstemon spp. (con.)	
PEHE2	heterodoxus	Heretic penstemon
PEHU	humilis	Low penstemon
PEJA	jamesii	James penstemon
PEJO	jonesii	Jones penstemon
PEKE2	keckii	Keck penstemon
PEKE	kennedyi	Kennedy penstemon
PEKI	kingii	Kings penstemon
PELA	laetus	Gay penstemon
PELA2	laevis	
PELA3	laxus	Idaho penstemon
PELE	leiophyllus	
PELE5	lemhiensis	Lemhi penstemon
PELE3	lentus	
PELE4	leonardii	Leonard penstemon
PELI	linarioides	Toadflax penstemon
PEMI2	miser	Malheur penstemon
PEMO	moffattii	
PEMO2	monoensis	
PEMO3	montanus	Cordroot penstemon
PENA	nanus	Dwarf penstemon
PENE	newberryi	Newberry penstemon
PENI	nitidus	Waxleaf penstemon
PEOS	osterhoutii	Osterhout penstemon
PEPA2	pachyphyllus	Thickleaf penstemon
PEPA	palmeri	Palmer penstemon
PEPA5	parvus	
PEPA6	payettensis	
PEPA7	paysoniorum	
PEPE2	perpulcher	Minidoka penstemon
PEPE3	petiolatus	
PEPL2	platyphyllus	Hillside penstemon
PEPR	procerus	Littleflower penstemon
PERA2	radicosus	Matroot penstemon
PERO	rothrockii	Rothrock penstemon
PERU	rubicundus	
PERY	rydbergii	Rydberg penstemon
PESC	scapoides	Inyo penstemon
PESC2	scariosus	
PESE3	seorsus	
PESE4	sepalulus	Littlecup penstemon
PESP	speciosus	Royal penstemon
PESP2	spectabilis	Showy penstemon
PEST	strictus	Rocky mountain penstemon
PESU	subglaber	
PESU2	suffrutescens	
PETE	teucrioides	Grayleaf creeping penstemon
PETH	thompsoniae	Thompson penstemon
PETH2	thurberi	Thurber penstemon

	tidestromii	Tidestrom
PEUI	uintahensis	Uinta penstemon
PEUT	utahensis	Utah penstemon
PEVI	virens	Green penstemon
PEVI2	virgatus	Wandbloom penstemon
PEWA	wardii	Wards penstemon
PEWA2	watsonii	Watson penstemon
PEWH	whippleanus	Whipple penstemon
PEPLI	Peplis spp.	
PEDI2	diandra	
PERE2	Perezia spp.	Perezia
PEWR	wrightii	
PERIC	Pericome spp.	Pericoma
PECA3	caudata	Tailleaf pericoma
PERID	Perideridia spp.	False caraway
PEBO	bolanderi	Bolander false caraway
PEGA	gairdneri	Yampa
PEPA8	parishii	
PERIT	Perityle spp.	
PEEM	emoryi	
PETA1	Petalonyx spp	Sandpaper plant
PENI2	nitidus	Smooth sandpaper plant
PEPA9	parryi	
PETH3	thurberi	Thurber sandpaper plant
PETA2	Petalostemon spp. (see Dalea)	Prairie clover
PECA4	candidum	White prairie clover
PEFL2	flavescens	Yellow prairie-clover
PEOR	ornatum	Showy prairie clover
PESE5	searlsiae	Searls prairie-clover
PETRO	Petrophytum spp.	Rockmat
PECAC	caespitosum caespitosum	Tufted rockmat
PECAE	caespitosum elatius	
PHACE	Phacelia spp.	Phacelia
PHAD	adenophora	
PHAF	affinis	
PHAN	anelsoni	
PHAU2	austromontana	
PHBA	barnebyana	
PHBI	bicolor	
PHCA3	calthifolia	

	cephalotes	
PHCOR	constancei	
PHCRC	crenulata corrugata	
PHCR	cryptantha	
PHCU	curvipes	
PHDE	demissa	
PHDI	distans	
PHFI	filiformis	
PHFR3	fremontii	
PHFR2	frigida	
PHGE	geraniifolia	
PHGL	glabberrima	
PHGL2	glandulifera	
PHGL3	glandulosa	Glandular phacella
PHGL4	glechomifolia	
PHGY	gymnoclada	
PHHA	hastata (alpina)	
PHHE	heterophylla	Varileaf phacelia
PHHO	howelliana	
PHHU	humilis	
PHHY	hydrophylloides	
PHID	idahoensis	Idaho phacelia
PHIN	incana	
PHIN2	inconspicua	
PHIN3	indecora	
PHIN4	integrifolia	
PHIN5	inundata	
PHIV	ivesiana	
PHLA	laxiflora	
PHLE2	lemmonii	
PHLI	linearis	Threadleaf phacelia
PHLU	lutea	
PHLY	lyallii	Lyall phacelia
PHMI	minutissima	
PHMU2	mustelina	
PHNE	neglecta	
PHNE2	neomexicana	
PHNE3	nevadensis	
PHPA	palmeri	
PHPA2	parishii	
PHPE	pediculoides	
PHPE2	peirsoniana	
PHPU	pulchella	
PHRA	ramosissima	Branching phacelia
PHRA2	rattanii	
PHRO	rotundifolia	
PHSA	saxicola	
PHSE	sericea	Silky phacelia
PHSP	splendens	
PHTA	tanacetifolia	Tansy phacelia

FORBS

PHACE	Phacelia spp. (con.)	
PHTE	tetramera	
PHTH	thermalis	
PHUT	utahensis	
PHVA	vallis-mortae	
PHLOX	Phlox spp	Phlox
PHAC	aculeata	Idaho phlox
PHAL3	albomarginata	White-margined phlox
PHAU	austromontana	Desert phlox
PHCL	cluteana	
PHCO3	condensata (caespitosa)	
PHDI	diffusa	
PHGL5	gladiformis (gooddingii)	
PHHOC	hoodii canescens	Hoods phlox
PHKE	kelseyi	Kelsey phlox
PHLO	longifolia	Longleaf phlox
PHMU	multiflora	Flowery phlox
PHMU3	muscoides	
PHPU2	pulvinata	
PHSP2	speciosa	Showy phlox
PHST	stansburyi	Stansbury phlox
PHVI	viscida	Sticky phlox
PHOEN	Phoenicaulis spp	Phoenicaulis
PHCH	cheiranthoides	Wallflower phoenicaulis
PHEU	eurycarpa	
PHOLI	Pholistoma spp	Lilia
PHME	membranaceum	
PHORA	Phoradendron spp	Mistletoe
PHBOD	bolleanum densum	Dense mistletoe
PHCA2	californicum	Mesquite mistletoe
PHFL	flavescens	Christmas mistletoe
PHJU	juniperinum	Juniper mistletoe
PHYSA	Physalis spp	Groundcherry
PHCR2	crassifolia	
PHFE	fendleri	
PHHE2	hederaefolia	Clammy groundcherry
PHLO2	longifolia	Longleaf groundcherry
PHYS2	Physaria spp	Twinpod
PHAC2	acutifolia	Common twinpod
PHCH2	chambersii	

FORBS

PHYS2	Physaria spp. (con.)	
PHCO	condensata	
PHFL	floribunda	Double bladderpod
PHGR	grahamii	
PHNE4	newberryi	Newberry twinpod
PHOR	oregana	
PISUM	Pisum spp	Pea
PISA	sativum	Garden pea
PITYR	Pityrogramma spp	Goldfern
PITR	triangularis	
PLAGI	Plagiobothrys spp.	Popcornflower
PLAR	arizonicus	
PLHA	harknessii	
PLHI	hispidulus	Hairy popcornflower
PLJO	jonesii	Jones popcornflower
PLKI	kingii	
PLMO	mollis	
PLSC	scouleri	Scouler popcornflower
PLTE	tenellus	
PLANT	Plantago spp.	Plantain
PLEL	elongata	
PLER	eriopoda	Redwool plantain
PLIN	insularis	Desert Indian wheat
PLLA	lanceolata	Buckhorn plantain
PLMA5	major	Rippleseed plantain
PLMA2	maritima	European seaside plantain
PLPA	patagonica purshii	Wooly plantain
PLTW	tweedyi	Tweedy plantain
PLATY	Platystemon spp	Platystemon
PLCA	californicus	Creamcup platystemon
PLECT	Plectritis spp	Plectritis
PLMA	macrocera	Longhorn plectritis
PLUCH	Pluchea spp	Pluchea
PLCA	camphorata	Camphor pluchea

[illegible]	ea twoodiae	
PONE4	nevadensis	
POLAN	Polanisia spp.	Clammyweed
PODO	dodecandra	
POTR4	trachysperma	Roughseed clammyweed (Western clammyweed)
POLEM	Polemonium spp.	Polemonium
POEX	eximium	
POFO	foliosissimum (albiflorum)	Leafy polemonium
POMI	micranthum	Littlebells polemonium
POOC	occidentale	Western polemonium
POPUP	pulcherrimum pulcherrimum	Skunkleaf polemonium
POPUC	pulcherrimum calycinum	
POPUD	pulcherrimum delicatum	
POVIV	viscosum viscosum	Sticky polemonium
POVIM	viscosum mellitum	
POLYC	Polyctenium	
POFR3	fremontii	
POLY2	Polygonatum spp.	Solomonseal
POCO6	commutatum	Great Solomonseal
POLY3	Polygonum spp.	Knotweed, smartweed
POAM2	amphibium	Water ladysthumb
POAU	austinae	Austin knotweed
POAV	aviculare (buxiforme)	Prostrate knotweed
POBI	bistortoides	American bistort
POCO3	coccineum	Bigroot ladysthumb
POCO4	confertiflorum	
POCO	convolvulus	Dullseed cornbind
POCU3	cuspidatum	Japanese fleece-flower
PODOD	douglasii douglasii	Douglas knotweed
PODOJ	douglasii johnstonii, sawatchense	Sawatch knotweed
POEN	engelmannii	
POER	erectum	Erect knotweed
POES	esotericum	
POEX2	exsertum	
POHE	heterosepalum	
POHY	Hydropiper	Marsh pepper smartweed
POHY2	hydropiperoides	Swamp smartweed
POKE	kelloggii	Kellogg knotweed
POLA	lapathifolium	Curlytop ladysthumb
POMA2	majus	
POMI2	minimum	Broadleaf knotweed
POPE	pensylvanicum	Pennsylvania smartweed
POPE2	persicaria	Spotted ladysthumb
POPH	phytolaccaefolium	Pokeweed fleece-flower
POPO	polycnemoide	
POPO2	polygaloides	Polygala knotweed
POPR3	prolificum	
POPU5	punctatum	Dotted smartweed
PORA	ramosissimum	Bush knotweed
PORE2	reynoutria	
POSH	shastense	
POSP	spergulariaeforme	
POVI2	viviparum	Viviparous bistort
POUT	utahense	
POWA	watsonii	Watson knotweed
POLYP	Polypodium spp.	Polypody
POVUC	vulgare columbianum	Western polypody
POLYS	Polystichum spp.	Hollyfern
POLO	lonchitis	Mountain hollyfern
POSC2	scopulinum	Eaton hollyfern
POROP	Porophyllum spp.	Poreleaf
POGR5	gracile	Slender poreleaf
PORTE	Porterella spp.	
POCA7	carnosula	
PORTU	Portulaca spp.	Portulaca
POMU	mundula	
POOL	oleracea	Common purslane
PORE3	retusa	
POTAM	Potamogeton spp.	Pondweed
POAL3	alpinus	Slimleaf pondweed
POAM5	amplifolius	Largeleaf pondweed
POBE	berchtoldii	
POCR	crispus	Curly pondweed
PODI	diversifolius	Waterthread pondweed
POEP2	epihydrus	Ribbonleaf pondweed

FORBS

POTAM	Potamageton spp. (con.)	
POFI	fibrillosus	Fineleaf pondweed
POFI2	filiformis	
POFO2	foliosus	Leafy pondweed
POFR2	friesii	Fries pondweed
POGR3	gramineus	Variableleaf pondweed
POIL	illinoensis	Illinois pondweed
POLA2	latifolius	Broadleaf pondweed
PONA	natans	Floatingleaf pondweed
PONO	nodosus	Longleaf pondweed
POPE3	pectinatus	Fennell leaf pondweed
POPR4	praelongus	Whitestem pondweed
POPU2	pusillus	Baby pondweed
PORI	richardsonii	Richardson pondweed
PORO	robbinsii	Robbins pondweed
POST2	strictifolius	Narrowleaf pondweed
POZO	zosteriformis	Flatstem pondweed
POTEN	Potentilla spp.	Cinquefoil
POAN2	anserina	Silverweed cinquefoil
POAR5	argentea argentea	Silver cinquefoil
POAR6	arguta convallaria	
POBI5	biennis	Biennial cinquefoil
POBL	blaschkeana	Blaschke cinquefoil
POBR	brevifolia	
POBR2	breweri	Brewer cinquefoil
POCO2	concinna	Elegant cinquefoil
POCR2	crinita	
PODI2	diversifolia	Varileaf cinquefoil
PODR	drummondii	Drummond cinquefoil
POGLG	glandulosa glandulosa	Gland cinquefoil
POGLA	glandulosa arizonica	
POGLI	glandulosa intermedia	
POGLM	glandulosa micropetala	
POGLN	glandulosa nevadensis	

FORBS

POTEN	Potentilla spp. (con.)	
POGLP	glandulosa pseudorupestris	
POGLR	glandulosa reflexa	
POGR4	gracilis (filipes) (jucunda) (nuttallii)	Northwest cinquefoil
POGL5	gracilis	Beauty cinquefoil
POHI	hippiana	Horse cinquefoil
POMI3	millefolia	
PONE5	newberryi	
PONI	nivea	
PONO2	norvegica	Norwegian cinquefoil
POOV	ovina	
POPA3	palustris	Marsh cinquefoil
POPA4	paradoxa	
POPE4	pennsylvanica	Pennsylvania cinquefoil
POPL	plattensis	Platte cinquefoil
POPS	pseudosericea	
POPU	pumila	Petty cinquefoil
POQU	quinquefolia	
PORI2	rivalis	Brook cinquefoil
POSA2	saxosa	
POSU2	sulfurea	
PRIMU	Primula spp.	Primrose
PRCU	cusickiana	
PRHU	hunnewellii	
PRIN	incana	American primrose
PRMA	maguirei	
PRPA	parryi	Parry primrose
PRSP	specuicola	
PROBO	Proboscidea spp.	Devilsclaws
PRPA2	parviflora	New Mexico devilsclaws
PRUNE	Prunella spp.	Selfheal
PRVU	vulgaris	Common selfheal
PSATH	Psathyrotes spp.	
PSAN	annua	
PSPI	pilifera	
PSRA	ramosissima	
PSEUD	Pseudocymopterus spp.	False spring parsley
PSMO	montanus	
PSVU2	vulgaris	Mountain parsley
PSILA	Psilactis spp.	
PSCO	coulteri	

PSBR	brevissimus	
PSOR	oregonus	
PSIL2	Psilostrophe spp.	Paperflower
PSBA	bakeri	
PSCO2	cooperi	Whitestem paperflower
PSSP	sparsiflora	Greenstem paperflower
PSTA	tagetinae	Woolly paperflower
PSORA	Psoralea spp.	Scurf-pea
PSBI	bituminosa	Arabian scurf-pea
PSCA	castorea	Beaverbread scurf-pea
PSEP	epipsila	
PSJU	juncea	
PSLA	lanceolata (stenostachys)	Lemmon scurf-pea
PSME	megalantha	
PSME2	mephitica	Skunktop scurf pea
PSPA	pariensis	
PSTE	tenuiflora	Slimflower scurf-pea
PTERI	Pteridium spp	Bracken
PTAQ	aquilinum	Western bracken fern
PTERO	Pterospora spp.	Pinedrops
PTAN	andromedea	Woodland pinedrops
PTER2	Pterostegia spp.	
PTDR	drymarioides	
PURPU	Purpusia spp	
PUSA	saxosa	
PYROL	Pyrola spp	Pyrola, shinleaf, wintergreen
PYAS	asarifolia	Alpine pyrola
PYDE	dentata	Toothleaf pyrola
PYEL	elliptica	Waxflower pyrola
PYMI	minor	Snowline pyrola
PYPI	picta	Whitevein pyrola
PYSE	secunda	Sidebells pyrola
PYUN	uniflora	Woodnymph
PYVI	virens	
	chlorantha	Green pyrola

RACA	californica	
RANE	neomexicana	
RAILL	Raillardella spp.	
RASC	scaposa	
RANUN	Ranunculus spp.	Buttercup, crowfoot
RAAC	acriformis	Sharp buttercup
RAAC2	acris	Tall buttercup
RAAD	adoneus	Alpine buttercup
RAAL	alismaefolius	Dwarf plainleaf buttercup
RAAN	andersonii	Anderson buttercup
RAAQ	aquatilis	Hairleaf water buttercup
RAAR	arvensis	Corn buttercup
RACA2	cardiophyllus	Shore buttercup
RACY	cymbalaria	Rocky Mountain buttercup
RAESE	eschscholtzii eschscholtzii	Eschscholtz buttercup
RAESS	eschscholtzii suksdorfii	Suksdorf buttercup
RAFL	flabellaris	Yellow buttercup
RAFL2	flammula reptans	Spearwort buttercup or Creeping spearwort buttercup
RAGL	glaberrimus	Sagebrush buttercup
RAGM	gmelinii	
RAIN	inamoenus	
RAJO	jovis	
RAJU	juniperinus	
RALO	longirostris	Longbeak buttercup
RAMA	macounii	
RAOC	occidentalis	Western buttercup
RAOR	oreogenes	
RAOR2	oresterus	
RAOR3	orthorhynchus	Straight-beak buttercup
RAPE	pedatifidus	
RAPE2	pennsylvanicus	Pennsylvania buttercup
RARA	ranunculinus	
RARE	repens	Creeping buttercup
RASC2	sceleratus	Blister buttercup
RATE	testiculatus	Bur buttercup
RAUN	uncinatus	

FORBS

RATIB	Ratibida spp	Prairie coneflower
RACO	columnifera	Upright prairie coneflower
RAPI	pinnata	
REVER	Reverchonia spp	
REAR	arenaria	
RHYSO	Rhysopteris spp	
RHPL	plurijugus	
RIGIO	Rigiopappus spp.	Wireweed
RILE2	leptocladus	
ROEME	Roemeria spp	Asiapoppy
RORE	refracta	Spotted asiapoppy
RORIP	Rorippa spp.	Yellowcress or Watercress
ROAL	alpina	
ROAU	austriaca	Austrian watercress
ROCU	curvipes	Obtuse fieldcress
ROIS	islandica	Marsh yellowcress
RONA	nasturtium	Watercress
ROSI	sinuata	Spreading yellowcress
ROSP	sphaerocarpa	
ROTE	tenerrima	
RUBIA	Rubia spp.	
RUTI	tinctorum	Madder
RUDBE	Rudbeckia spp	Coneflower
RULA	laciniata	Cutleaf coneflower
RUOC	occidentalis	Western coneflower
RUMEX	Rumex spp.	Dock, sorrel
RUAC	acetosella	Sheep sorrel
RUAL	altissimus	Great dock
RUCA	californicus	
RUCO	conglomeratus	Clustered dock
RUCR	crispus	Curly dock
RUCU	cuneifolius	
RUDE	densiflorus	
RUFE	fenestratus	
RUFU	fueginus	Golden dock
RUHY	hymenosepaulus	Canaigre
RULA2	lacustris	
RUME	mexicanus	Mexican dock
RUOB	obtusifolius	Bitter dock
RUOC2	occidentalis	Western dock
RUPA3	patientia	Patience dock
RUPA2	paucifolius	Mountain sorrel
RUSA	salicifolius	Willow dock
RUSU	subalpinus	

FORBS

RUMEX	Rumex spp. (con.)	
RUUT	utahensis	
RUVE	venosus	Veiny dock
RUPPI	Ruppia spp	Widgeonweed
RUMA	maritima	Widgeongrass
RUPE	pectinata	Floating widgeongrass
SAGIN	Sagina spp	Pearlwort
SAOC	occidentalis	
SASA	saginoides	Arctic pearlwort
SAGIT	Sagittaria spp.	Arrowhead
SACU	cuneata	Duckpotato arrowhead
SALA	latifolia	Common arrowhead
SAMO	montevidensis	Giant arrowhead
SALIC	Salicornia spp	Glasswort, samphire, pickleweed
SAEU	europaea	Marshfire glasswort
SAPA	pacifica	
SAUT	utahensis	Utah glasswort, samphire
SALSO	Salsola spp	Russianthistle
SAIB	iberica	Saltwort
SAPE	pestifer (kali)	Russianthistle
SALVI	Salvia spp.	Sage
SAAE	aethiopis	California chia (Mediterranean sage)
SABE	beckeri	
SABE2	betonicaefolia	
SACO2	columbariae	Californiachia sage
SASC2	sclarea	Clary sage
SAMOL	Samolus spp.	Waterpimpernel
SAFL	floribundus	
SANGU	Sanguisorba spp.	Burnet
SAMI	minor	Small burnet
SAOC2	occidentalis	Western burnet
SARU	ruprechtii	
SASI	sitchensis	Sitka burnet
SANIC	Sanicula spp.	Sanicle
SACR	graveolens	

SAOC3	ocymoides	Rock soapwort
SAOF	officinalis	Bouncing-bet
SAVA	vaccaria	Cow soapwort
SARC2	Sarcodes spp.	Snowplant
SASA2	sanguinea	Snowplant
SARC3	Sarcostemma spp.	Climbing milk weed
SACY	cynanchoides	
SAHI	hirtellum	
SAXIF	Saxifraga spp.	Saxifrage
SAAD	adscendens	
SAAP	aprica	
SABR2	bronchialis	Yellowdot saxifrage
SACA2	caespitosa	
SACE2	cernua	
SACH	chrysantha	Goldbloom saxifrage
SADE	debilis	
SAFE	ferruginea	Rustyhair saxifrage
SAFL2	flagellaris	
SAIN	integrifolia	Columbian saxifrage
SAME	mertensiana	Mertens saxifrage
SANI	nidifica	
SAOC4	occidentalis	Alberta saxifrage
SAOD	odontoloma	Washington saxifrage
SAOP	oppositifolia	Twinleaf saxifrage
SAOR2	oregana	Oregon saxifrage
SARH	rhomboidea	Diamondleaf saxifrage
SATO	tolmiei	Tolmie saxifrage
SCHEU	Scheuchzeria spp.	Scheuchzeria
SCPA2	palustris	Scheuchzeria
SCOPU	Scopulophila spp.	
SCRI	rixfordii	
SCORP	Scorpiurus spp.	Scorpiontail
SCSU2	subvillosa	Caterpillarpod scorpiontail
SCVE	vermiculatus	Wormpod scorpiontail

SCROP	Scrophularia spp.	Figwort
[illegible]	[illegible]	
SCLA	lanceolata	Lanceleaf figwort
SCUTE	Scutellaria spp.	Skullcap
SCAN	angustifolia	Narrowleaf skullcap
SCAN2	antirrhinoides	
SCGA	galericulata	
SCNA	nana	
SEDUM	Sedum spp.	Stonecrop
SEDE	debile	
SELA	lanceolatum	Lanceleaved sedum
SEOB	obtusatum	
SERH	rhodanthum	Redpod stonecrop
SERO	rosea	Roseroot stonecrop
SELAG	Selaginella spp.	Selaginella, spikemoss
SEDED	densa densa	Spikemoss selaginella
SEDES	densa scopulorum	Rocky Mt. spikemoss selaginella
SEDO	douglasii	Douglas selaginella
SELE	leucobryoides	
SEMU	mutica	
SESE2	selaginoides	
SEUN	underwoodii	Underwood selaginella
SEUT	utahensis	Utah selaginella
SEWA	watsonii	Watson selaginella
SELIN	Selinocarpus spp.	Moonpod
SEDI	diffusus	Moonpod
SENEC	Senecio spp.	Groundsel, ragwort, butterweed
SEAM	amplectens	Showy alpine groundsel
SEAR	aronicoides	Rayless groundsel
SEAT	atratus	Black groundsel
SEAU	aureus	Golden groundsel
SEBI	bigelovii	Bigelow groundsel

SENEC	Senecio spp	(con.)
SECA	canus	Woolly groundsel
SECO	[illegible]	
SECR	crassulus	Thickleaf groundsel
SECR2	crocatus	Saffron groundsel
SECY	cymbalarioides	Cleftleaf groundsel
SEDE2	debilis	
SEDI2	dimorphophyllus	
SEDO2	douglasii	Douglas groundsel
SEER	eremophilus (ambrosioides)	Desert groundsel
SEEU	eurycephalus	
SEFE	fendleri	Fendler groundsel
SEFRF	fremontii fremontii	Fremont groundsel
SEFRB	fremontii, blitoides	
SEFRO	fremontii occidentalis	
SEHA	hartianus	
SEHY	hydrophilus	Water groundsel
SEIN2	indecorus	
SEIN	integerrimus (columbianus)	Lambstongue groundsel
SELO	longilobus	Threadleaf groundsel
SEMI	millelobatus (uintahensis)	Uinta groundsel
SEMU2	multilobatus	Lobeleaf groundsel
SEMU3	mutabilis	
SENE	neomexicanus	New Mexico groundsel
SEPA	pattersonianus	
SEPA2	pauperculus	Balsam groundsel
SEPS	pseudaureus	Golden groundsel
SEPU	pudicus	Butterweed groundsel
SESE	serra	Butterweed groundsel
SESP	spartioides	Broom groundsel
SESP2	sphaerocephalus	
SEST2	streptanthifolius	
SETR	triangularis	Arrowleaf groundsel
SEVU	vulgaris	Common groundsel
SEWE	werneriaefolius	
SEWO	wootonii	Wooton senecio
SESUV	Sesuvium spp.	Sesuvium, seaparslane
SEVE	verrucosum	

SIBAR	Sibara spp	
SIDE	desertii	
SIBBA	Sibbaldia spp.	
SIPR	procumbens	
SIDA	Sida spp	Sida
SIHE	hederacea	Alkali sida
SIDAL	Sidalcea spp.	Checkermallow
SICA	candida	White checkermallow
SIGL	glaucescens	Bird checkermallow
SIMU	multifida	
SINE	neomexicana	New Mexico checkermallow
SIOR	oregana (nervata)	Oregon checkermallow
SILEN	Silene spp	Silene
SIAC	acaulis	Moss silene
SIAL2	alpina	
SIAN	antirrhina	Sleepy silene
SIAR	armeria	Sweet william silene
SICL	clokeyi	Clokey silene
SICU	cucubalus	Bladder silene
SIDO	douglasii (lyallii)	Douglas silene
SIME	menziesii	Menzies silene
SIMO	montana	
SINO	noctiflora	Nightflowering silene
SINU	nuda	
SIOR2	oregana	Oregon silene
SIPA	parryi	Parry silene
SIPE	petersonii	
SIRE	rectiramea	
SIRE2	repens	
SISA	sargentii	
SISC	scaposa	
SISC2	scouleri	Scouler silene
SISP	spaldingii	
SIVE	verecunda	
SILYB	Silybum spp	Milkthistle
SIMA	marianum	Blessed milkthistle
SISYM	Sisymbrium spp (see Chlorocrambe)	Tumblemustard
SIAL	altissimum	Tumblemustard
SIAM	ambiguum	
SIIR	irio	London racket tumblemustard
SILO2	loeselii	Hedgemustard

SISYR	Sisyrinchium spp.	Blue-eyed-grass
SIBE	bellum	Western blue-eyed-grass
SIDO2	douglasii	Douglas blue-eyed-grass
SIHA2	halophilum	
SIID	idahoensis	Idaho blue-eyed-grass
SIIN	inflatum	
SIMO2	montanum	Colorado blue-eyed-grass
SIOC	occidentale	Montana blue-eyed-grass
SIRA	radicatum	
SISA2	sarmentosum	
SIUM	Sium spp.	Waterparsnip
SISU	suave	Hemlock waterparsnip
SMELO	Smelowskia spp.	Smelowskia
SMCA	calycina	
SMHO	holmgrenii	
SMILA	Smilacina spp.	Solomon-plume; false Solomon-seal
SMRAA	racemosa amplexicaulis	Fat Solomon plume
SMST	stellata	Starry Solomon-plume
SOLAN	Solanum spp.	Nightshade
SOCA	carolinense	Carolina horsenettle
SODU	dulcamara	Bitter nightshade
SOEL	elaeagnifolium	Silverleaf nightshade
SOJA	jamesii	James nightshade
SONI	nigrum	Black nightshade
SORO	rostratum	Buffalobur nightshade
SOSA	sarachoides	
SOTR	triflorum	Cutleaf nightshade
SOLID	Solidago spp.	Goldenrod
SOCA2	canadensis (elongata)	Canada goldenrod
SOCO	confinis	
SOGI	gigantea	Giant goldenrod
SOGR	graminifolia	Grassleaf goldenrod

	sis (concinna)	Missouri goldenrod
SOMO	mollis	Velvety goldenrod
SOMU	multiradiata (ciliosa)	Low goldenrod
SONA	nana	Baby goldenrod
SONE	nemoralis	Dyersweed goldenrod
SOOC	occidentalis	Western goldenrod
SOPA	parryi	Parry goldenrod
SORI	rigida	Stiff goldenrod
SOSE	serotina	Smooth goldenrod
SOSP3	sparsiflora	
SOSP	spathulata	Coast goldenrod
SOSP2	spectabilis	Nevada goldenrod
SOTE	tenuifolia	
SONCH	Sonchus spp.	Sowthistle
SOAR	arvensis	Field sowthistle
SOAS	asper	Prickly sowthistle
SOOL	oleraceus	Common sowthistle
SOUL	uliginosus	
SOPHO	Sophora spp.	Sophora
SONU	nuttalliana	Silky sophora
SOST	stenophylla	Fringeleaf sophora
SPERG	Spergula spp.	Spurry
SPAR	arvensis	Corn spurry
SPER2	Spergularia spp.	Sandspurry
SPAT	atrosperma	
SPMA	marina	Saltmarsh sandspurry
SPRU	rubra	Red sandspurry
SPHAE	Sphaeralcea spp.	Globemallow
SPAM	ambigua	Desert globemallow
SPCA	caespitosa	Tufted globemallow
SPCO2	coccinea	Scarlet globemallow
SPDI	digitata	
SPEM	emoryi	
SPFE	fendleri	Fendler globemallow
SPFR	fremontii	Fremont globemallow
SPGR	grossulariaefolia	Gooseberryleaf globemallow
SPIN	incana	

SPLAM	Sphaeralcea spp. (con.)	
SPLE	leptophylla	
SPMU	munroana	Munro globemallow
SPPA	parvifolia	
SPRE	remota	
SPRI	rivularis	Stream globemallow
SPRU	rusbyi	
SPSU	subhastata	
SPHA	Sphaerophysa spp. (Swainsona)	Swainsonpea
SPSA2	salsula	Salt globepea
SPHE2	Sphenosciadium spp.	Woollyheadparsnip
SPCA	capitellatum	Range woollyhead parsnip
SPIR	Spiranthes spp.	Ladies tresses
SPPO	porrifolia	Creamy ladies tresses
SPRO	romanzoffiana	[illegible] ladies tresses
SPIRO	Spirodela spp.	Great duckmeat
SPPO2	polyrhiza	Common duckmeat
STAC	Stachys spp.	Betony, hedge nettle
STAL	albens	
STPA	palustris	Marsh betony
STRI	rigida	
STRO	rothrockii	
STTE	teucriiformis	
STAN	Stanleya spp.	Princesplume
STAL2	albescens	Arizona princesplume
STCO	confertiflora	
STPI	pinnata	Desert princesplume
STIN	integrifolia	Wholeleaf desert princesplume
STAN3	Stanleyella spp. see Thelypodium	
STEIR	Steironema spp. see Lysimachia	
STEL	Stellaria spp.	Starwort
STCA1	calycantha interior	Northern starwort
STCR	crispa	
STJA	jamesiana	Tuber starwort
STLO	longifolia	
STLO2	longipes	Longstalk starwort
STME	media	Chickweed
STEL	Stellaria spp. (con.)	
STNI	nitens	
STOB	obtusa	
STUM	umbellata	
STEPH	Stephanomeria spp.	Wirelettuce
STEX	exigua	
STLA	lactucina	
STLY	lygodesmoides	
STPA2	paniculata	
STPA	pauciflora	
STTE2	tenuifolia	Slender wirelettuce
STVI2	virgata	
STILL	Stillingia spp.	Stillingia
STSP	spinulosa	
STREP	Streptanthella spp.	
STLO3	longirostris	
STRE	Streptanthus spp.	Twistflower
STCO3	cordatus	Heartleaf twistflower
STRE2	Streptopus spp.	Twisted-stalk
STAM	amplexifolius	Claspleaf twisted-stalk
STYLO	Stylocline spp.	
STFI	filaginea	
STMI	micropoides	
STPS	psilocarphoides	
SUAE	Suaeda spp.	Seepweed
SUDE	depressa	Pursh seepweed
SUFR	fruticosa	Alkali seepweed
SUNI	nigra	
SUOC	occidentalis	Western seepweed
SUSU	suffrutescens	Desert seepweed
SUTO	torreyana	Torrey seepweed
SUBU	Subularia spp.	Awlwort
SUAQ	aquatica	Water awlwort
SUKS	Suksdorfia spp.	Suksdorfia
SURA	ranunculifolia	
SWER	Swertia spp.	Swertia
SWPE	perennis	Alpinebog swertia

SYPI	pinnatifida	Featherleaf kittentails
SYNTR	Syntrichopappus spp.	
SYFR	fremontii	
TALIN	Talinum spp.	Fameflower
TABR	breviflorum	
TAPA	parviflorum	Prairie fameflower
TAVA	validulum	
TANAC	Tanacetum spp.	Tansy
TACA2	canum	
TACA	caroliniensis	
TANU	nuttallii	
TAPO	potentilloides	
TAVU	vulgare	Common tansy
TARAX	Taraxacum spp.	Dandelion
TACE	ceratophorum	Rough dandelion
TAER	eriophorum	
TALA	laevigatum	Smooth dandelion
TALY	lyratum	
TAOF	officinale	Common dandelion
TELES	Telesonix spp.	
TEJA	jamesii	
TEUCR	Teucrium spp.	Germander; woodsage
TECA2	canadense	American germander
THALI	Thalictrum spp.	Meadowrue
THAL	alpinum	Alpine meadowrue
THDA	dasycarpum	Purple meadowrue
THFE	fendleri	Fendler meadowrue
THOC	occidentale	Western meadowrue
THSP	sparsiflorum	
THVE	venulosum	Veiny meadowrue
THELE	Thelesperma spp.	Greenthread
THMA	marginatum	
THME	megapotamicum	
THSU	subnudum	Navajo-tea greenthread
THEL2	Thelypodiopsis spp.	
THAU	aureum	
THEL	elegans	
THWY	wyomingensis	

THEU	eucosum	
THFL	flexuosum	
THHO	howellii	Howell thelypody
THIN	integrifolium	Entireleaved thelypody
THLA	laciniatum	Cutleaved thelypody
THLA2	lasiophyllum	
THRO	rollinsii	
THSA	sagittatum	
THWR	wrightii	
THERM	Thermopsis spp.	Thermopsis
THCA	cardinians	
THMO	montana	Mountain thermopsis
THPI	pinetorum	Pine thermopsis
THLAS	Thlaspi spp.	Pennycress
THAR	arvense	Field pennycress
THMO3	montanum	Blue pennycress
THYSA	Thysanocarpus spp.	Lacepod
THAM	amplectens	
THCU	curvipes	
THLA3	laciniatus	
TIARE	Tiarella spp.	Foamflower
TITR	trifoliata	Trefoil foamflower
TIDES	Tidestromia spp.	Tidestromia
TILA	lanuginosa	Woolly tidestromia
TIOB	oblongifolia	Honeysweet tidestromia
TILLA	Tillaea spp.	Pigmyweed
TIAQ	aquatica	Common pigmyweed
TOFIE	Tofieldia spp.	Tofieldia
TOGL	glutinosa	Tofieldia
TOWNS	Townsendia spp	Townsendia
TOAN	annua	
TOAP	aprica	
TOCO	condensata	
TOEX	exscapa	Stemless townsendia
TOFL	florifer (ambigua)	
TOHO	hookeri	Hooker townsendia
TOIN	incana	Hoary townsendia

FORBS

TOWNS	Townsendia spp. (con.)	
TOJO	jonesii	
TOLE	leptotes	
TOME	mensana	
TOMI	minima	
TOMO	montana	Mountain townsendia
TOPA2	parryi	Parry townsendia
TOSP	spathulata	
TOST	strigosa	Hairy townsendia
TRADE	Tradescantia spp.	Spiderwort
TROC	occidentalis	Prairie spiderwort
TRPI	pinetorum	Woods spiderwort
TRAGI	Tragia spp.	Noseburn
TRST	stylaris	
TRAGO	Tragopogon spp.	Goatsbeard, salsify
TRDU	dubius	Yellow salsify
TRPO	porrifolius	Vegetable-oyster salsify
TRPR	pratensis	Meadow salsify
TRAUT	Trautvetteria spp.	False-bugbane
TRCA	carolinensis	
TRIAN	Trianthema spp.	Horse purslane
TRPO2	portulacastrum	Desert horse-purslane
TRIBU	Tribulus spp.	Puncturevine, caltrop
TRTE	terrestris	Puncturevine
TRICA	Tricardia spp.	
TRWA	watsonii	
TRIC2	Trichoptilium spp.	
TRIN	incisum	
TRIC3	Trichostema spp.	Bluecurls
TRAU	austromontanum	
TROB	oblongum	
TRSI	simulatum	
TRIFO	Trifolium spp.	Clover
TRAG	agrarium	Hop clover
TRAM	ambiguum	Kura clover
TRAN	andersonii	Fiveleaf clover
TRAN2	andinum	
TRBE2	**beckwithii**	**Beckwith clover**

FORBS

TRIFO	Trifolium spp. (con.)	
TRCA2	campestre	Large hopclover
TRCH	cherleri	
TRCY	cyathiferum	Cup clover
TRDA	dasyphyllum	Whiproot clover
TRDO	douglasii	Douglas clover
TRDU2	dubium	Suckling clover
TRER	eriocephalum	Woollyhead clover
TRFE	fendleri	Fendler clover
TRFR	fragiferum	Strawberry clover
TRGE	gemellum	
TRGL	glomeratum	Cluster clover
TRGY	gymnocarpon	Hollyleaf clover
TRHI	hirtum	Rose clover
TRHY	hybridum	Alsike clover
TRKI	kingii	Kings clover
TRLA	lappaceum	Burdock clover
TRLE	leibergii	
TRLE2	lemmonii	Lemmons clover
TRLO	longipes longipes	Longstalk clover
TRLOR	longipes reflexum	
TRMA	macilentum	Utah clover
TRMA2	macrocephalum	Bighead clover
TRMI	microcephalum	Littlehead clover
TRMO	monanthum	Carpet clover
TRMO2	monoense	Mono clover
TRNA	nanum	Dwarf clover
TRPA	parryi	Parry clover
TRPI3	pinetorum	
TRPL	plumosum	Pussy clover
TRPR2	pratense	Red clover
TRPR3	procumbens	Low hop clover
TRPR4	productum	
TRRE	repens	White clover
TRRE2	resupinatum	Persian clover
TRST2	striatum	Knotted clover
TRSU	subterraneum	Subterranean clover
TRVA	variegatum	Whitetip clover
TRWI	willdenovii	Sierra clover
TRIGL	Triglochin spp.	Podgrass, arrowgrass
TRCO	concinna	
TRDE	debilis	
TRMA3	maritima	Shore podgrass
TRPA2	palustris	Arrow podgrass
TRIGO	Trigonella spp.	Trigonella
TRFO	foenum graecum	Fenugreek trigonella

[illegible]	[illegible]	[illegible]
TROV	ovatum	Pacific trillium
TRPE	petiolatum	Idaho trillium
TRIOD	Triodanis spp	
TRPE2	perfoliata	Clasping venus lookingglass
TRIXI	Trixis spp	Trixis
TRCA5	californica	American trixis
TROLL	Trollius spp	Globeflower
TRLA2	laxus	American globeflower
TYPHA	Typha spp	Cattail
TYDO	domingenesis	Dominican cattail
TYGL	glauca godron	
TYLA	latifolia	Common cattail
URTIC	Urtica spp.	Nettle
URDI	dioica	Big stinging nettle
URHO	holosericea	California slim nettle
URLY	lyallii	Lyall nettle
URSE	serra	
UTRIC	Utricularia spp	Bladderwort
UTIN	intermedia	
UTMI	minor	Lesser bladderwort
UTVU	vulgaris	Common bladderwort
VACCA	Vaccaria spp	Soapwort
VASE	segetalis	Cow soapwort
VALE6	Valeriana spp	Valerian
VAAC	acutiloba	Sharpleaf valerian
VAAR	arizonica	Arizona valerian
VAED	edulis	Edible valerian
VAOC	occidentalis micrantha	Western valerian
VALE2	Valerianella spp	Cornsalad
VALO	locusta	
VANCL	Vanclevea spp.	
VAST	stylosa	
VECA	californicum	California false-hellebore
VEES	eschscholtzii	Eschscholtz false-hellebore
VERBA	Verbascum spp	Mullein
VEBL	blattaria	Moth mullein
VETH	thapsus	Flannel mullein
VERBE	Verbena spp.	Verbena
VEBR	bracteata	Bigbract verbena
VECA2	canescens	
VECA3	carolina	
VEGO	gooddingii	
VEHA	hastata	Blue verbena
VEMA	macdougalii	
VERB2	Verbesina spp.	Crownbeard
VEEN	encelioides	Golden crownbeard
VERON	Veronica spp.	Speedwell
VEAM	americana	American speedwell
VEAN	anagallis-aquatica	Water speedwell
VEAR	arvensis	Common speedwell
VEBE	beccabunga	Beccabunga speedwell
VEBI	biloba	
VECA4	catenata	
VECU	cusickii	
VEHE	hederaefolia	Ivyleaf speedwell
VEPE	peregrina	Purslane speedwell
VEPE2	persica	Birdseye speedwell
VESC	scutellata	Marsh speedwell
VESE	serpyllifolia	Thymeleaf speedwell
VEWO	wormskjoldii	Wormskjold speedwell
VICIA	Vicia spp	Vetch
VIAMM	americana minor	American vetch
VIAMT	americana truncata	Bluntleaf American vetch
VICR	cracca	Bird vetch
VIEX	exigua	Slim vetch
VIHI	hirsuta	Tiny vetch
VISA	sativa	Common vetch
VITE	tenuifolia	Bramble vetch
VIVI	villosa	Hairy vetch

VIGUI	Viguiera spp.	Goldeneye
VIAN	annua	Annual goldeneye
VICI	ciliata	Hairy goldeneye
VIDE	deltoidea	Shrubby goldeneye
VIMUM	multiflora multiflora	Showy goldeneye
VIMUN	multiflora nevadensis	Nevada showy goldeneye
VISO	soliceps	
VIOLA	Viola spp	Violet
VIAD	adunca	Hook violet
VIAR	arvensis	Field violet
VIBE	beckwithii	Beckwith violet
VICA	canadensis	Canada violet
VICH	charlestonensis	
VIGL	glabella	Pioneer violet
VIMA	macloskeyi	Macloskey violet
VINE	nephrophylla	Wanderer violet
VINUN	nuttallii nuttallii (lineariaefolia)	Nuttall violet
VINUV	nuttallii vallicola	
VIOD	odorata	Sweet violet
VIPA	palustris	Marsh violet
VIPR	praemorsa	Yellow violet
VIPU	purpurea	Goosefoot violet
VIUT	utahensis	Utah violet
WISLI	Wislizenia spp	Jackass clover
WIRE	refracta	
WOLFF	Wolffia spp.	Watermeal
WOPU	punctata	
WOODS	Woodsia spp.	Woodsia
WOME	mexicana	Mexican woodsia
WOOR	oregana	Oregon woodsia
WOPL	plummerae	Plummer woodsia
WOSC	scopulina	Rocky Mountain woodsia
WOODW	Woodwardia spp.	Chainfern
WOFI	fimbriata	Western chainfern
WYETH	Wyethia spp.	Wyethia
WYAM	amplexicaulis	Mulesears wyethia
WYAR	arizonica	Arizona wyethia
WYHE	helianthoides	Whitehead wyethia

WYETH	Wyethia spp.	(con.)
WYMO	mollis	Woolly wyethia
WYSC	scabra	Badlands wyethia
XANTH	Xanthium spp.	Cocklebur
XASP	spinosum	Spiny cocklebur
XAST	strumarium	
XEROP	Xerophyllum spp.	Beargrass
XETE	tenax	Common beargrass
ZANNI	Zannichellia spp.	Poolmat
ZAPA	palustris	Common poolmat
ZAUSC	Zauschneria spp	Firechalice
ZAGA	garrettii	Garrett firechalice
ZIGAD	Zigadenus spp	Deathcamas
ZIEL	elegans	Mountain deathcamas
ZIPA	paniculatus	Foothill deathcamas
ZIVE	venenosus	Meadow deathcamas
ZIGR2	gramineus	Grassy deathcamas
ZIVA	vaginatus	
ZINNI	Zinnia spp	Zinnia
ZIGR	grandiflora	Rocky Mountain zinnia
ZIZIA	Zizia spp.	Zizia
ZIAP	aptera	
ZUCKI	Zuckia spp.	
ZUAR	arizonica	
ZYGOP	Zygophyllum spp.	Beancaper
ZYFA	fabago	Syrian beancaper

ABCO	concolor	White fir
ABGR	grandis	Grand fir
ABLA	lasiocarpa	Subalpine fir
ABMA	magnifica	California red fir
ACACI	Acacia spp.	Acacia
ACGR2	greggii	Catclaw acacia
ACAMP	Acamptopappus spp.	Goldenhead
ACSH	shockleyi	Shockley goldenhead
ACSPS	sphaerocephalus sphaerocephalus	Rayless goldenhead
ACSPH	sphaerocephalus hirtellus	
ACER	Acer spp.	Maple
ACGI	ginnala	Amur maple
ACGLG	glabrum glabrum	Rocky Mountain maple
ACGLD	glabrum diffusum	
[illegible]	glabrum douglasii	Douglas Rocky Mountain maple
ACGLN	glabrum neomexicanum	
ACGLT	glabrum torreyi	
[illegible]	glabrum tripartitum	
ACGR	grandidentatum	Bigtooth maple
ACMA	macrophyllum	Bigleaf maple
ACNEN	negundo negundo	Boxelder
ACNEI	negundo interius	Inland or Manitoba boxelder
ACNI	nigrum	Black maple
ACPL	platanoides	Norway maple
[illegible]	Aesculus spp.	Horsechestnut or Buckeye
[illegible]	hippocastanum	Common horsechestnut
[illegible]	Aesculus spp.	Horsechestnut or Buckeye
[illegible]	glabra glabra	Ohio buckeye
AEHI	hippocastanum	Common horsechestnut
[illegible]	[illegible]	Yellow buckeye

AGDE	deserti	Desert agave
AGKA	kaibabensis	Kaibab agave
AGUT	utahensis	Utah agave
AILAN	Ailanthus spp.	Ailanthus
AIAL	altissima	Tree of heaven ailanthus
ALHAG	Alhagi spp.	
ALCA	camelorum	Camelthorn
ALLEN	Allenrolfea spp.	Iodine bush
ALOC	occidentalis	Iodine bush
ALNUS	Alnus spp.	Alder
ALOB	oblongifolia	New Mexico alder
ALRH	rhombifolia	White Sierra alder
ALSI2	sinuata	
ALTE	tenuifolia	Thinleaf alder
AMBRO	Ambrosia spp. (Franseria)	Bur sage
AMDU	dumosa	White bur sage
AMER	eriocenta	Woolly bur sage
AMELA	Amelanchier spp.	Serviceberry
AMALA	alnifolia alnifolia	Saskatoon serviceberry
AMALC	alnifolia cusickii	Cusick serviceberry
AMALP	alnifolia pallida	Pale serviceberry
[illegible]	alnifolia pumila	Dwarf saskatoon
AMFL	florida	Pacific serviceberry
AMUTU	utahensis utahensis oreophila	Utah serviceberry
AMUTC	utahensis covillei	
AMORP	Amorpha spp.	Amorpha
AMCA	canescens	Leadplant amorpha
[illegible]	fruticosa	Indigobush amorpha
AMPHI	Amphipappus spp.	Chaff bush
AMFRF	fremontii fremontii	
AMFRS	fremontii spinosus	

TREES AND SHRUBS

ARCTO	Arctostaphylos spp.	Manzanita
ARNE	nevadensis	Pinemat manzanita
ARPA	parryana	Parry manzanita
ARPAP	parryana pinetorum	Pine manzanita
ARPA6	patula	Greenleaf manzanita
ARPU	pungens	Pointleaf manzanita
ARUV	uva-ursi	Bearberry
ARTEM	Artemisia spp.	Sagebrush, wormwood
ARAB	[illegible]	[illegible] wormwood
[illegible]	[illegible]	[illegible]
ARAR	arbuscula	Low sagebrush
ARBI	bigelovii	Bigelow sagebrush
ARCAB	campestris borealis	Sagewort wormwood
ARCAS	campestris borealis var. scouleriana	
ARCAC	cana cana	Silver sagebrush
ARCAV	cana viscidula	Mountain silver sagebrush
ARCAB	cana bolanderi	Bolander silver sagebrush
ARCA	carruthii	Carruth [illegible]
ARDO	douglasiana	
ARFI	filifolia	Sand sagebrush
ARFR	frigida	Fringed sagebrush
ARLO3	longifolia	Longleaf sagebrush
ARLO	longiloba	Alkali sagebrush
ARNO	nova	Black sagebrush
ARPA5	papposa	
ARPA6	parryi	
ARPE3	pedatifida	[illegible]
ARPY	pygmaea	Pygmy sagebrush
ARRI	rigida	Stiff sagebrush
ARRO	rothrockii	Timberline sagebrush
ARSP	spinescens	Bud sagebrush
ARTRT	tridentata tridentata	Basin big sagebrush
ARTRV	tridentata vaseyana	Mountain big sagebrush
ARTRW	tridentata wyomingensis	Wyoming big sagebrush
ARTRT	tripartita tripartita	Tall threetip sagebrush
ARTRR	tripartita rupicola	Wyoming threetip sagebrush

TREES AND SHRUBS

ATRIP	Atriplex spp.	Saltbush
ATBO	bonnevillensis	
ATCA	canescens	Fourwing saltbush
ATCO	confertifolia	Shadscale
ATCO2	corrugata	Mat saltbush
ATCU	cuneata	Castle valley clover
ATFA	falcata	
ATGA	gardneri	Gardner saltbush
ATGA2	garrettii	Garrett saltbush
ATHY	hymenelytra	Desertholly saltbush
ATLE	lentiformis	Big saltbush
ATNA	[illegible]	
ATOB	obovata	Broadscale saltbush
ATPA	parryi	Parry saltbush
ATPL	pleiantha	
ATPO	polycarpa	Cattle saltbush
ATTO	torreyi	
ATTR	tridentata	
ATTR2	truncata	Wedgescale saltbush
ATWE	welshii	Welsh saltbush
AVENI	Avenia spp.	Avenia
AVPU	pusilla	Dwarf avenia
BACCH	Baccharis spp.	Baccharis
BAEM	emoryi	Emory baccharis
BAGL	glutinosa	Seepwillow baccharis
BASA	sarothroides	[illegible] baccharis
BAVI	viminea	Mulefat baccharis
BAWR	wrightii	Wright baccharis
BEBBI	Bebbia spp.	Bebbia
BEJU	juncea	Rush bebbia
BERBE	Berberis spp. (Mahonia)	Barberry
BEAQ	aquifolium	Shining barberry
BEFR	fremontii	Fremont barberry
BEHA	haematocarpa	Red barberry
BERE	repens	Creeping barberry

BEIN	incana	
BETUL	Betula spp	Birch
BEGL	glandulosa	Bog birch
BEOCO	occidentalis occidentalis (frontinalis)	Water birch
BEOCI	occidentalis inopina	
BEPAP	papyrifera papyrifera	Western paper birch
BEPAC	papyrifera commutata	
BEPAS	papyrifera subcordata	Northwestern paper birch
BRIC2	Brickellia spp.	Brickellia
BRAT	atractyloides	Spiny brickellia
BRCA2	californica	California brickellia
BRDE	desertorum	Desert brickellia
BRFR	frutescens	Rigid brickellia
BRGR	grandiflora	Tassel flower brickellia
BRIN2	incana	White brickellia
BRLO	longifolia	Longleaf bricklellia
BRMIM	microphylla microphylla	Littleleaf
BRMIS	microphylla scabra	Rough brickellia
BRMU	multiflora	Inyo brickellia
BROBO	oblongifolia oblongifolia	Mohave brickellia
BROBL	oblongifolia linifolia	
BRWA	watsonii	Watson brickellia
BUDDL	Buddleja spp	Butterflybush
BUDA	davidii	Orange-eye butterflybush
BUHA	hartwegii	
BUUT	utahensis	Utah butterflybush
CANOT	Canotia spp	Canotia
CAHO	holacantha	Mohave canotia
CARAG	Caragana spp	Peashrub
CAAR	arborescens	Siberian peashrub
CAARP	arborescens pygmaea	Pygmy peashrub
CASSI	Cassia spp	Senna
CAAR	armata	Desert senna
CACO	covesii	Hairy senna

CASS2	Cassiope spp	Cassiope
	mertensiana	
CAMEG	mertensiana gracilis	
CEANO	Ceanothus spp	Buckbrush, ceanothus
CECO	cordulatus	Mountain whitethorn ceanothus
CECU2	cuneatus	Wedgeleaf ceanothus
CEFE	fendleri	Fendler ceanothus
CEGRG	greggii greggii	Mohave desert ceanothus
CEGRV	greggii vestitus	
CEINI	integerrimus integerrimus	Deerbrush ceanothus
CEINC	integerrimus californicus	
CELE3	lemmonii	Lemmon ceanothus
CELO	lorenzenii	
CEMA	martinii	Martin ceanothus
CEPR	prostratus	Squawcarpet ceanothus
CESA	sanguineus	Redstem ceanothus
CEVE	velutinus	Snowbrush ceanothus
CEDRU	Cedrus spp.	Cedar
CEDE	deodara	Deodar cedar
CELTI	Celtis spp.	Hackberry
CEDO	douglasii	Douglas hackberry
CEOC	occidentalis	Common hackberry
CERE	reticulata	Netleaf hackberry
CERA	Ceratoides spp. (Eurotia)	Winterfat
CELA	lanata lanata	Common winterfat
CELAS	lanata subspinosa	Bush winterfat
CERCI	Cercis spp	Redbud
CECA	canadensis	Eastern redbud
CEOC	occidentalis	California redbud
CERCO	Cercocarpus spp.	Mountain mahogany
CEBE	betuloides	Birchleaf mountain mahogany

[illegible] SHRUB

[illegible]	[illegible]	[illegible]
[illegible]	ledifolius intricatus	[illegible] mountain mahogany
[illegible]	ledifolius intercedens	
[illegible]	intricatus	Littleleaf mountain mahogany
[illegible]	montanus montanus	True mountain mahogany
[illegible]	montanus [illegible]	
[illegible]	montanus [illegible]	
CHAMA	Chamaebatiaria spp.	[illegible]
CHMI	millefolium	Desertsweet
CHILO CHLI	Chilopsis spp. linearis	Desert willow Desert willow
CHRY	Chrysothamnus spp.	Rabbitbrush
CHAL	[illegible]	Alkali rabbitbrush
CHDE CHGR	depressus greenei	Dwarf rabbitbrush Greene's rabbitbrush
CHHU	humilis	[illegible]
CHLI	linifolius	Spreading rabbitbrush
CHNAN	nauseosus nauseosus	Rubber rabbitbrush
CHNAA	nauseosus albicaulis	White rubber rabbitbrush
CHNA	nauseosus [illegible]	
CHNAB	nauseosus bigelovii	
CHNAC	nauseosus consimilis	Threadleaf rubber rabbitbrush
CHNAG	nauseosus glabratus	
CHNAG	nauseosus graveolens	
CHNAH	nauseosus hololeucus	[illegible] rubber rabbitbrush
CHNAJ	nauseosus junceus	
CHNAL	nauseosus [illegible]	[illegible] rabbitbrush
CHNAL	nauseosus leiospermus	
CHNAP	nauseosus [illegible]	

[illegible] SHRUB

[illegible]	Chrysothamnus spp.	[illegible]
[illegible]	[illegible] [illegible]	Mountain [illegible] [illegible]
[illegible]	[illegible] [illegible]	
[illegible]	[illegible] [illegible]	
CHPA	parryi parryi	[illegible] rabbitbrush
[illegible] [illegible]	[illegible] parryi attenuatus	
[illegible]	parryi howardii	[illegible] rabbitbrush
CHPAM	parryi monocephalus	
CHPAN	parryi nevadensis	
CHPAV	parryi vulcanicus	
CHPU	pulchellus	[illegible] rabbitbrush
[illegible]	[illegible]	Roundleaf rabbitbrush
CHVA	vaseyi	Vasey rabbitbrush
CHVI	viscidiflorus	Stickyleaf low rabbitbrush
CHVIL	viscidiflorus lanceolatus	Mountain low rabbitbrush
CHVIL	viscidiflorus latifolius	[illegible] rabbitbrush
CHVIP	viscidiflorus puberulus	[illegible] low rabbitbrush
CHVIS	viscidiflorus stenophyllus	Narrowleaf low rabbitbrush
CLEMA	Clematis spp.	Clematis, virgin's bower
[illegible] [illegible]	[illegible] [illegible]	Shortplume clematis
[illegible] [illegible]	[illegible] columbiana	[illegible] clematis
[illegible]	[illegible] [illegible]	
[illegible]	[illegible] [illegible]	
[illegible]	[illegible] ligusticifolia	Western virginsbower
[illegible]	[illegible] [illegible]	
[illegible]	[illegible]	

CLOR	orientalis	Oriental clematis
CLPS	pseudoalpina	Rocky Mountain clematis
COLEO	Coleogyne spp.	Blackbrush
CORA	ramosissima	Blackbrush
COLUT	Colutea spp.	Bladdersenna
COAR	arborescens	Common bladdersenna
COIS	istria	Mediterranean bladdersenna
CONDA	Condalia spp.	Condalia
COLYL	lycioides lycioides	[illegible] southwestern condalia
COLYC	lycioides canescens	
CORNU	Cornus spp.	Dogwood
COSTS	stolonifera stolonifera	Redosier dogwood
COSTO	stolonifera occidentalis	Western dogwood
COTON	Cotoneaster spp.	Cotoneaster
COAC	acutifolia	Peking cotoneaster
COIN	integerrima	European cotoneaster
COLU	lucida	Hedge cotoneaster
CORA	racemiflora	[illegible] cotoneaster
COTO	tomentosa	[illegible] cotoneaster
[illegible]	zabelii [illegible]	
COWAN	Cowania spp.	Cliffrose
COME	mexicana stansburiana	Stansbury cliffrose
CRATA	Crataegus spp.	Hawthorn
[illegible]	douglasii	Douglas hawthorn
[illegible]	rivularis	River hawthorn
[illegible]	[illegible]	[illegible] hawthorn
[illegible]	[illegible]	[illegible] hawthorn
[illegible]	Cupressus spp.	Cypress
[illegible]	arizonica [illegible]	Arizona cypress
[illegible]	[illegible]	[illegible] cypress
[illegible]	[illegible]	[illegible] bush
[illegible]	[illegible]	[illegible] dalea
DAFR	fremontii fremontii	Fremont dalea
DAFRM	fremontii minutifolia	[illegible], fremont dalea
DAFRP	fremontii [illegible]	[illegible] fremont dalea
DAFRS	fremontii saundersii	
DAKI	kingii	King dalea
DAMO	mollissima	
DAPO	polyadenia	Nevada dalea
DASE	searlsiae	
DATH	thompsonae	Thompson dalea
DRYAS	Dryas spp.	Dryad
DROCA	octopetala angustifolia	
DROCH	octopetala hookeriana	Mt. Washington dryad
ECHIN	Echinocactus spp.	Hedgehog cactus
ECAC	acanthodes	Barrel cactus
ECPOX	polycephalus xeranthemoides	Cotton-top echinocactus
ECHI	Echinocereus spp.	Echinocereus
ECEN	engelmannii	Engelmann echinocereus
ECFE	fendleri	Fendler echinocereus
ECTRM	triglochidiatus mojavensis	
ECTR	triglochidiatus [illegible]	Claret cup echinocereus
ELAEA	Elaeagnus spp.	Elaeagnus
ELAN	angustifolia	Russian olive
ELCO	commutata	Silverberry
ELUM	umbellata	Autumn elaeagnus
ENCEL	Encelia spp.	Encelia
ENFA	farinosa	[illegible], brittlebush
ENFR	frutescens frutescens	Bush encelia
[illegible]	frutescens actoni	
ENFRR	frutescens [illegible]	
ENFRV	frutescens virginensis	

EPHED	Ephedra spp.	Ephedra, jointfir, Mormon tea
EPAS	aspera	Rough ephedra
EPCU	cutleri	Cutler ephedra
EPFA	fasciculata fasciculata	
EPFAC	fasciculata clokeyi	
EPNE	nevadensis	Nevada ephedra
EPTO	torreyana	Torrey ephedra
EPVI	viridis	Green ephedra
ERIOD	Eriodictyon spp	Yerba-santa
ERAN	angustifolium	Narrowleaf yerba-santa
ERIO2	Eriogonum spp.	Eriogonum or Wild buckwheat
ERDI	divergens	
EREFE	effasum effusum	Spreading buckwheat
EREFD	effusum durum	
EREFN	effusum nelsonii	
EREFO	effusum ordiculatum	
EREFS	effusum salinum	
EREF2	effusum shandsii	
ERFAP	fasciculatum polifolium	California flattop wild-buckwheat
ERFAR	fasciculatum revolutum	
ERFR	fruticulosum	
ERHE2	heracleoides	Wyeth eriogonum
ERMIM	microthecum microthecum	Slenderbush eriogonum
ERMIC	microthecum confertiflorum	
ERMI2	microthecum crispus	
ERMIE	microthecum expansum	
ERMIF	microthecum friscanum	
ERMI1	microthecum idahoense	
ERMI3	microthecum intermedium	
ERMI4	microthecum macdougalii	
EROV	ovalifolium	Cushion eriogonum
ERUM	umbellatum (neglectum)	Sulfur eriogonum

EUROT	Eurotia spp	(see Ceratoides)
FALLU	Fallugia spp.	Apache-plame
FAPA	paradoxa	Apache plume
FENDL	Fendlera spp.	Fendlerbush
FERU2	rupicola	Cliff fendlerbush
FEND2	Fendlerella spp.	Fendlerella
FEUT	utahensis	Utah fendlerella
FEROC	Ferocactus spp	Ferocactus
FEACL	acanthodes lecontei	
FICUS	Ficus spp	Fig
FICA	carica	Common fig (white genoa)
FORES	Forestiera spp	Forestiera
FONE	neomexicana	New Mexican forestiera
FOPH	phillyreoides	New Mexican olive forestiera
FRAN2	Franseria spp.	(see Ambrosia)
FRAXI	Fraxinus spp	Ash
FRAM	americana	White ash
FRAN	anomala	Singleleaf ash
FRANL	anomala lowellii	Lowell singleleaf ash
FRCUM	cuspidata macropetala	Fragrant ash
FRDI2	dipetala	Two-petal ash
FRPE	pennsylvanica	Green ash
FRVE2	velutina	Velvet ash
GARRY	Garrya spp	Silktassel
GAFLF	flavescens flavescens	Yellowleaf silktassel
GAFLP	flavescens pallida	
GAWR	wrightii	Wright silktassel
GAULT	Gaultheria spp	Honeylocust
GAHI	hispidula	Creeping snowberry
GAHU3	humifusa	Western honeylocust
GAOV	ovatifolia	Slender wintergreen
GLEDI	Gleditsia spp.	Honeylocust
GLTR	triacanthos	Common honeylocust

GLME	meionandra	
GLNEN	nevadense nevadense	
GLNES	nevadense var. stipuliferum	
GLPU	pungens	Dwarf greasebush
GRAY1	Grayia spp.	Hopsage
GRBR	brandegei	Spineless hopsage
GRSP	spinosa	Spiny hopsage
GUTIE	Gutierrezia spp.	(see Xanthocephalum)
GYMN2	Gymnocladus spp.	Coffeetree
GYDI	dioicus	Kentucky coffeetree
HALIM	Halimodendron spp.	Salt-tree
HAHA	halodendron	Siberian salt-tree
HALLI	Hallophytum spp.	Chuckawallabush
HAHA2	hallii	Halls chuckawallabush
HAPL2	Haplopappus spp.	Goldenweed
HABL	bloomeri	Rabbitbrush goldenweed
HABR	brickellioides	Brickell goldenweed
HACE	cervinus	
HACU2	cuneatus	Wedgeleaf goldenweed
HALI	linearifolius	Narrowleaf goldenweed
HAMA	macronema	Whitestem goldenweed
HANA	nanus	Dwarf goldenweed
HARA	racemosus	
HARY	rydbergii	Rydberg goldenweed
HASC	scopulorum	
HASU	suffruticosus	Singlehead goldenweed
HAWA	watsonii	Watson goldenweed
HOLOD	Holodiscus spp.	Ocean-spray
HOBO	boursieri	
HODI	discolor	Rockspirea (creambush)

	dumosus	ocean-spray
HODUG	dumosus glabrescens	
HOUST	Houstonia spp.	Bluets
HORU	rubra	
HYMEN	Hymenoclea spp.	Burrobrush
HYSA	salsola	White burrobrush
JAMES	Jamesia spp.	Jamesia
JAAMA	americana americana	Cliff jamesia
JAAMC	americana californica	California cliff jamesia
JANUS	Janusia spp.	Janusia
JACR	gracilis	Slender janusia
JUGLA	Juglans spp.	Walnut
JUMA	major	Arizona black walnut
JUNI	nigra	Eastern black walnut
JUNIP	Juniperus spp.	Juniper
JUCOS	communis saxatilis	Mountain common juniper
JUHO	horizontalis	Creeping juniper
JUMO	monosperma	One-seed juniper
JUOC	occidentalis	Sierra juniper
JUOS	osteosperma (utahensis)	Utah juniper
JUSC	scopulorum	Rocky Mountain juniper
KALMI	Kalmia spp.	Laurel, kalmia
KAPOM	polifolia microphylla	Alpine bog kalmia
KOCHI	Kochia spp.	Summer cypress
KOAMA	americana americana	Green molley summer cypress or red sage
KOAMV	americana vestita	Gray summer cypress
KOPR	prostrata	Prostrate summer cypress
KOELR	Koelreuteria spp.	Goldrain-tree
KOPA	paniculata	Panicled goldenrain

KRAME	Krameria spp.	Krameria
KRGR	grayi	Gray krameria
KRPA	parvifolia glandulosa	Littleleaf krameria
KRPAI	parvifolia imparata	
LAPHA	Laphamia spp.	
LACO	congesta	
LAFA	fastigiata	
LAGR	gracilis	
LAIN	intricata	
LAPAP	palmeri palmeri	
LAST	stansburii	
LARIX	Larix spp.	Larch
LAOC	occidentalis	Western larch
LARRE	Larrea spp.	Creosotebush
LADI	divaricata	Spreading creosote bush
LEDUM	Ledum spp.	Ledum
LEGL	glandulosum	Western ledum
LEPI3	Lepidospartum spp.	Scalybroom
LELA	latisquamum	Woolly scalybroom
LEPT2	Leptodactylon spp.	
LECA3	caespitosa	Mat prickly phlox
LEPU	pungens	Prickly phlox
LEPUH	pungens hallii	Granite prickly phlox
LEWA	watsonii	Watson prickly phlox
LIBOC	Libocedrus spp.	Incensecedar
LICH	chilensis	Chilean incensecedar
LIDE	decurrens	California incensecedar
LIPPI	Lippia spp.	Lippia
LIWR	wright lippia	
LONIC	Lonicera spp.	Honeysuckle
LOAR	arizonica	Arizona honeysuckle
LOCA3	caerulea	Sweetberry honeysuckle
LOCI2	ciliosa	Western trumpet honeysuckle
LOCO2	conjugialis	Purpleflower honeysuckle
LOIN	involucrata	Bearberry honeysuckle
LOPR	prolifera	Grape honeysuckle

LONIC	Lonicera spp. (con.)	
LOTA	tatarica	Tatarian honeysuckle
LOUT	utahensis	Utah honeysuckle
LUPI2	Lupinus spp.	Lupine
LUBR2	breweri	Brewers lupine
LUEX	excubitus	Inyo lupine
LUEXH	excubitus hallii	Halls lupine
LYCIU	Lycium spp.	Matrimony vine, wolfberry
LYAN	andersonii	Anderson wolfberry
LYBA	barbarum (halimifolium)	Matrimony vine
LYCO2	cooperi	Cooper wolfberry
LYPAP	pallidum pallidum	Pale wolfberry
LYPAO	pallidum oligospermum	
LYTO	torreyi	Torrey wolfberry
MACLU	Maclura spp.	Osage-orange
MAPO	pomifera	Osage-orange
MAHON	Mahonia spp.	(See Berberis)
MALUS	Malus spp.	Crabapple
MABR2	bracteata	Buncombe crabapple
MAHO	hopa	Hopa crabapple
MENOD	Menodora spp.	Menodora
MESC	scabra	Rough menodora
MESP2	spinescens	Spiny menodora
MORUS	Morus spp.	Mulberry
MOALT	alba tatarica	Russian mulberry
NEOLL	Neolloydia spp.	Button cactus
NEJO	johnsonii	
OPUNT	Opuntia spp.	Pricklypear, cholla
OPAC	acanthocarpa	Buckhorn cholla
OPBA	barkleyana	
OPBAB	basilaris basilaris	Beavertail pricklypear
OPBAA	basilaris aurea	Golden pricklypear
OPBAW	basilaris whitneyana	
OPBI	bigelovii	Arizona jumping pricklypear
OPCH	chlorotica	Dollarjoint pricklypear
OPEC	echinocarpa	Strawtop pricklypear

OPUNT Opuntia spp. (con.)

		pricklypear
OPFRF	fragilis fragilis	Brittle pricklypear
OPFRD	fragilis denudata	
OPGR	gracilicylindrica	
OPHY	hystriciana	
OPLA	laevis	Smooth pricklypear
OPPA	parishii	Parish cholla
OPPH	phaeacantha	
OPPO	polyacantha	Plains prickypear
OPPUP	pulchella pulchella	
OPPUB	pulchella brachyrhopolica	
OPPUT	pulchella tuberculosi rhopalica	
OPPY	pygmaea	
OPRA	ramosissima	Holycross cholla
OPRH	rhodantha	
OPRU	rubrifolia	
OPSP	spectatissima	
OPWH	whipplei	Whipple cholla
OPWE	weigandii	
OPWO	woodsii	
OSTRY	Ostrya spp.	Hophornbeam
OSKN	knowltonii	Knowlton hophornbeam
PACHI	Pachistima spp	Pachistima
PAMY	myrsinites	Myrtle pachistima
PARR2	Parryella spp.	
PAFI2	filifolia	Dunebroom
PARO	rotundata	
PARTH	Parthenium spp.	Parthenium
PAIN	incanum	Mariola parthenium
PART2	Parthenocissus spp.	Creeper
PAIN2	inserta	Thicket creeper
PEDIO	Pediocactus spp.	
PESI	sileri	
PESI2	simpsonii	
PEPA5	paradinei	
PENS2	Penstemon spp.	Penstemon
PEBRF	breviflorus breviflorus	Stubflower penstemon

PENS2 Penstemon spp. (con.)

	glabrisepalus	
PEFRF	fruticosus fruticosus	Bush penstemon
PEFRS	fruticosus scouleri	
PEFR2	fruticosus serratus	
PELE2	lemmoni	Lemmon penstemon
PERAP	Peraphyllum spp.	
PERA	ramosissimum	Squaw-apple
PEUCE	Peucephyllum spp.	Sprucebush, pigmycedar
PESC2	schottii	Schotts sprucebush
PHILA	Philadelphus spp.	Mockorange, syringa
PHLE	lewisii	Lewis mockorange
PHMIM	microphyllus microphyllus	Littleleaf mockorange
PHMIA	microphyllus argenteus	
PHMIO	microphyllus occidentalis	
PHMI2	microphyllus ovatus	
PHMIS	microphyllus stramineus	
PHYLL	Phyllodoce spp.	Mountainheath
PHEM	empetriformis	Red mountainheath
PHGL6	glanduliflora	Cream mountainheath
PHYSO	Physocarpus spp	Ninebark
PHAL2	alternans	Dwarf ninebark
PHIN6	intermedius	Illinois ninebark
PHMA	malvaceus	Mallow ninebark
PHMO2	monogynus	Mountain ninebark
PICEA	Picea spp.	Spruce
PIEN	engelmannii	Englemann spruce
PIPU	pungens	Colorado blue spruce
PINUS	Pinus spp.	Pine
PIAL	albicaulis	Whitebark pine
PICO	contorta (latifolia)	Lodgepole pine
PIED	edulis	Pinyon
PIFL	flexilis	Limber pine
PIJE	jeffreyi	Jeffrey pine
PILO	longaeva	Bristlecone pine
PILA	lambertiana	Sugar pine

PINUS	Pinus spp. (con.)	
PIMO	monophylla	Singleleaf pinyon pine
PIMO3	monticola	Western white pine
PIPO	ponderosa	Ponderosa pine
PIWA	washoensis	
PLUC2	Pluchea spp.	Pluchea
PLSE	sericea	Marsh fleabane
POLIO	Poliomintha spp.	Rosemarymint
POIN2	incana	Hoary rosemary mint
POLYG	Polygala spp.	Polygala
POACA	acanthoclada acanthoclada	Thorn polygala
POACI	acanthoclada intricata	
POSUS	subspinosa subspinosa	Spiny polygala
POSUH	subspinosa heterorhyncha	
	(Polygonum spp. — see Forbs)	
POPUL	Populus spp.	Aspen, poplar, cottonwood
POAC	acuminata	Lanceleaf cottonwood
POAL2	alba alba	White poplar
POALP	alba pyramidalis	Bolleana poplar
POAN	angustifolia	Narrowleaf cottonwood
POBA	balsamifera	Balsam poplar
POCA2	canadensis	Carolina or Gray poplar
PODE	deltoides	Eastern cottonwood
POFRF	fremontii fremontii	Fremont cottonwood
POFRW	fremontii wislizenii	Rio Grande cottonwood
PONII	nigra italica	Black poplar
POSA	sargentii	Plains cottonwood
POTR	tremuloides	Quaking aspen
POTR5	trichocarpa	Black cottonwood (California poplar)
POTE2	Potentilla	Cinquefoil
POFR	fruticosa	Bush cinquefoil

PROS2	Prosopis spp.	Mesquite
PRJUT	juliflora torreyana	Mesquite
PRPU	pubescens	Screwbean mesquite
PRUNU	Prunus spp.	Plum, cherry
PRAM	americana	American plum
PRAN	andersonii	Anderson peachbrush
PRAR	armeniaca	Apricot
PRBE	besseyi	Bessey cherry
PRDE	demissa	
PRDO	domestica	Garden plum
PREM	emarginata	Bitter cherry
PRFA	fasciculata	Desert peachbrush
PRFR	fruticosa	
PRIL	ilicifolia	Hollyleaf cherry
PRJA	japonica	Chinese bushcherry
PRPAC	padus commutata	Harbinger europea birdcherry
PRPE	persica	Peach
PRSE	serotina	Black cherry
PRSI	siberica	Sloe cherry
PRSP2	spinosa	Klamath plum
PRSU	subcordata	
PRTE	tenella	
PRTO	tomentosa	
PRVID	virginiana demissa	Western common chokecherry
PRVIM	virginiana melanocarpa	Black common chokecherry
PSEU2	Pseudotsuga spp.	Douglas fir
PSMEM	menziesii menziesii (taxifolia)	Douglas-fir
PSMEG	menziesii glauca	Rocky Mountain Douglas-fir
PTELE	Ptelea spp.	Hoptree
PTBA	baldwinii	Baldwin hoptree
PTPA	pallida	Pale hoptree
PTPO	polyadenia	
PTTR	trifoliata	Common hoptree
PURSH	Purshia spp.	Bitterbrush
PUGL	glandulosa	Desert bitterbrush
PUTR	tridentata	Antelope bitterbrush
QUERC	Quercus spp.	Oak
QUCHC	chrysolepis chrysolepis	Canyon live oak

	palmeri	
QUGA	gambelii	Gambel oak
QUGR	grisea	Gray oak
QUMA	macrocarpa	Bur oak
QUPA	palustris	Pin oak
QUTU	turbinella	Shrub live oak
QUUN	undulata	Wavyleaf oak
RHAMN	Rhamnus spp	Buckthorn
RHAL	alnifolia	Alder buckthorn
RHBEO	betulaefolia obovata	Birchleaf buckthorn
RHCAU	californica ursina	California buckthorn
RHCA	cathartica	Common buckthorn
RHDA	davurica	Dahurian buckthorn
RHER	erythroxylon	
RHLI	libanotica	Lebanon buckthorn
RHOL	oleoides	
RHPE	petiolaris	Petioled buckthorn
RHPU	purshiana	Cascara buckthorn
RHRU	rubra	
RHSA	saxatilis	Rock buckthorn
RHSM	smithii	Buckthorn
RHSP	spathulaefolia	
RHTI	tinctoria	Dyers buckthorn
RHUS	Rhus spp	Sumac
RHGLC	glabra cismontana	Rocky Mountain smooth sumac
RHMI	microphylla	Littleleaf sumac
RHRA	radicans (toxicodendron rydbergii	Poison sumac
RHTRT	trilobata trilobata	Skunk bush sumac
RHTRA	trilobata anisophylla	
RHTRQ	trilobata quinata	
RHTRS	trilobata simplicifolia	
RHTY	typhina	Staghorn sumac
RIBES	Ribes spp	Currant, gooseberry
RIAU	aureum	Golden currant
RICEC	cereum cereum	Wax currant
RICEI	cereum inebrians	Squaw currant

RIHE	hendersonii	Henderson gooseberry
RIIN	inerme	Whitestem gooseberry
RILA	lacustre	Prickly currant
RILE	leptanthum	Trumpet gooseberry
RIMO	montigenum	Gooseberry currant
RINE	nevadense	Sierra currant
RINI	niveum	Snow gooseberry
RIPE	petiolare	Western black currant
RISE	setosum	Missouri gooseberry
RIVEV	velutinum velutinum	Desert gooseberry
RIVEG	velutinum goodingii	Gooding gooseberry
RIVIV	viscosissimum viscosissimum	Sticky currant
RIVIH	viscosissimum hallii	Hills currant
RIWO	wolfii	Rothrock currant
ROBIN	Robinia spp	Locust
RONE	neomexicana	New Mexico locust
ROPS	pseudoacacia	Black locust
ROSA	Rosa spp.	Rose
ROAC	acicularis	Prickly rose
ROCO	collaris	
ROEG	eglanteria	Sweetbrier rose
ROGY	gymnocarpa	Baldhip rose
ROLA	laxton	
ROMA	manca	Mancos rose
ROMU	multiflora	Japanese rose
RONUH	nutkana hispida (spaldingii	Bristly nootka rose
ROST	stellata	Desert rose
ROWOU	woodsii ultramontana	Woods rose
RUBUS	Rubus spp	Blackberry or Raspberry
RUDI	discolor	Himalaya blackberry
RUIDS	idaeus sachalinensis (strigosus)	American red raspberry
RULAN	laciniatus neomexicanus	New Mexican raspberry
RUPA	parviflorus	Japanese raspberry

TREES AND SHRUBS

SALAZ	Salazaria spp	Bladdersage
SAME2	mexicana	Mexican Bladdersage
SALIX	Salix spp.	Willow
SAAM	amygdaloides	Peachleaf willow
SAAR	arctica	Arctic willow
SABA	babylonica	babylon weeping willow
SABAP	barclayi padophylla	Barclay willow
SABEP	bebbiana perrostrata	Smooth bebb willow
SABR	brachycarpa	Barrenground willow
SACA	cascadensis	Cascades willow
SACO	commutata	Undergreen willow
SADR	drummondiana	Drummond willow
SAEXE	exigua exigua	Coyote willow
SAEXM	exigua melanopsis	Dusky willow
SAEXS	exigua stenophylla	
SAGE	geyeriana	Geyer willow
SAGL	glauca	Grayleaf willow
SAJE	jepsonii	Jepson willow
SALA2	laevigata	Polished willow
SALA2	lasiandra	Pacific willow
SACA	caudata	Whiplash willow
SALA3	lasiolepis	Arroyo willow
SALE	lemmonii	Lemmons willow
SAMO2	monticola	
SAMY	myrtillifolia	Blueberry willow
SANIV	nigra venulosa	Black willow
SANIN	nivalis nivalis	Snow willow
SANIS	nivalis saximontana	
SAOR	orestera	Sierra willow
SAPHP	phylicifolia planifolia	Tealeaf willow
SAPH2	phylicifolia planifolia (monica)	
SAPUG	purpurea purpurea	Purpleosier willow
SARIM	rigida mackenziana	Mackenzie willow
SARIW	rigida watsonii (lutea)	Watson willow
SASC	scouleriana	Scouler willow
SATW	tweedyi	Tweedy's willow
SAWOW	wolfii wolfii	Wolfs willow
SAWOI	wolfii idahoensis	Idaho wolfs willow

TREES AND SHRUBS

SALVI	Salvia spp	Purple sage
SADOD	dorrii dorrii	
SADOA	dorrii argentea	
SADOC	dorrii carnosa	
SADOG	dorrii gilmanii	
SAMBU	Sambucus spp	Elder
SACE	cerulea (glauca)	Blueberry elder
SARPM	racemosa pubens melanocarpa	Black elder
SARP2	racemosa pubens microbotrys	Red elder
SARCO	Sarcobatus spp.	Greasewood
SAVEV	vermiculatus vermiculatus	Black greasewood
SAVEB	vermiculatus baileyi	Bailey greasewood
SCLER	Sclerocactus spp	Sclerocactus
SCME	mesae-verdae	
SCPO	polyancistrus	
SCWHI	whipplei intermedius	
SCWHP	whipplei pubispinus	
SCWHR	whipplei roseus	
SEQUO	Sequoia spp.	Sequoia
SEGI	giganteum	Giant sequoia
SHEPH	Shepherdia spp	buffaloberry
SHAR	argentea	Silver buffaloberry
SHCA	canadensis	Russet buffaloberry
SHRO	rotundifolia	Roundleaf buffaloberry
SIMMO	Simmondsia spp	Jojoba
SICH	chinensis	Goatnut jojoba
SOPH2	Sophora spp	Sophora
SOAR2	arizonica	Arizona sophora
SORBU	Sorbus spp	Mountain ash
SOAM	americana	American mountain-ash
SOAU	aucuparia	European mountain-ash
SOHY	hybrida	Oakleaf mountain-ash
SOSCC	scopulina cascadens	
SOSCS	scopulina scopulina	Greenes mountain-ash

		mountain-ash
SPIRA	Spiraea spp.	Spirea
SPCA3	caespitosa	
SPCA4	canescens	Hoary spirea
SPDE	densiflora	Subalpine spirea
SPDOR	douglasii roseata	Douglas spirea
SPLU	lucida	Shinyleaf spirea
SPPY	pyramidata	Pyramid spirea
SPSA	sargentiana	Sargent spirea
SYMPH	Symphoricarpos spp.	Snowberry
SYALA	albus albus	
SYALL	albus laevigatus	Garden common snowberry
SYALP	albus pauciflorus (racemosus)	Dwarf common snowberry
SYLO	longiflorus	Longflower snowberry
SYMOA	mollis acutus	Spreading snowberry
SYMOH	mollis hesperius	Creeping snowberry
SYOC	occidentalis	Western snowberry
SYORO	oreophilus oreophilus	Mountain snowberry
SYORU	oreophilus utahensis (vaccinoides)	
SYPA	parishii (rotundifolius)	Roundleaf snowberry
SYRA	racemosus	
SYRIN	Syringa spp.	Lilac
SYHE	henryi	Henry lilac
SYVI	villosa	Late lilac
SYVU	vulgaris	Common lilac
TAMAR	Tamarix spp.	Tamarisk
TAAP	aphylla	Athel tamarisk
TAPA2	parviflora	Fivestamen tamarisk
TARU	ramosissima	
TATE	tetrandra	Fourstamen tamarisk
TETRA	Tetradymia spp.	Horsebrush
TEAX	axillaris	Longspine horsebrush
TECA	canescens inermis	Gray horsebrush
TECO	comosa	Hairy horsebrush

		horsebrush
TENU	nuttallii	Nuttal horsebrush
TESP	spinosa	Cottonthorn horsebrush
THAMN	Thamnosma spp.	Desertrue
THMO2	montana	Mohave desertrue
TSUGA	Tsuga spp.	Hemlock
TSHE	heterophylla	Western hemlock
TSME	mertensiana	Mountain hemlock
ULMUS	Ulmus spp.	Elm
ULAM	americana	
ULPA	parvifolia	Chinese elm
ULPU	pumila	Siberian elm
VACCI	Vaccinium spp.	Blueberry, huckleberry whortleberry
VACA	caespitosum	Dwarf blueberry
VAGL	globulare	Globe huckleberry
VAME	membranaceum	Big whortleberry
VAMY	myrtillus (oreophilum)	Myrtle whortleberry
VAOC2	occidentale	Westernbog blueberry
VAOV	ovalifolium	Ovalleaf huckleberry
VAOX	oxycoccos	Wild cranberry
VASC	scoparium	Grouse whortleberry
VITIS	Vitis spp.	Grape
VIARA	arizonica arizonica	Canyon grape
VIARG	arizonica glabra	
XANT2	Xanthocephalum spp. (Gutierrezia)	Matchbrush snakeweed
XAMI	microcephala	Threadleaf snakeweed
XASA	sarothrae	Broom snakeweed
YUCCA	Yucca spp.	Yucca
YUAN	angustissima	Fineleaf yucca
YUBAB	baccata baccata	Datil yucca
YUBAV	baccata vespertina	
YUBA2	baileyi baileyi	
YUBAN	baileyi navajoa	

YUCCA	Yucca spp. (con.	
YUBRB	brevifolia brevifolia	Joshua tree yucca
YUBRJ	brevifolia jaegeriana	
YUEL	elata	Soaptree yucca
YUHA	harrimaniae	Harriman yucca
YUKA	kanabensis (glauca)	
YUNE	neomexicana	Spanish bayonet
YUSC	schidigera	Mohave yucca
YUTO	toftiae	
YUUT	utahensis	
ZELKO	Zelkova spp.	Zelkova
ZESE	serrata	Japanese zelkova

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MOUNTAIN FOREST
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THE NATIONAL FIRE-DANGER RATING SYSTEM — 1978

John E. Deeming
Robert E. Burgan
Jack D. Cohen

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

- Billings, Montana
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RESEARCH SUMMARY

The 1978 National Fire-Danger Rating System (NFDRS) updates the danger rating system developed in the early 1970's and published by Deeming and others in 1972. Numerous changes have been made to correct deficiencies and to incorporate new technology. The most significant of the changes are:

1. Improving the response to drought.
2. Increasing the sensitivity of the ratings, particularly in the lower fire-danger ranges.
3. Reflecting the effect of changing day length on burning conditions.
4. Improved accounting of fuels through improvement of the existing fuel models and the addition of the 11 more fuel models.
5. Separating the occurrence indexes for man-caused and lightning-caused fires.
6. Developing predictive models for the moisture contents of live grasses and forbs, and woody shrubs.

The results of this work are presented in two publications. This publication covers the general information on the NFDRS and its application; a second publication (Burgan and others 1977) contains the nomograms and directions for calculating fire-danger ratings manually.

CONTENTS

Page

Preface. vi

UPDATING THE NATIONAL FIRE-DANGER RATING SYSTEM 1

PRINCIPLES OF THE NATIONAL FIRE-DANGER RATING SYSTEM 3

STRUCTURE OF THE NATIONAL FIRE-DANGER RATING SYSTEM 5

THE NATIONAL FIRE-DANGER RATING SYSTEM COMPONENTS 7

FIRE LOAD INDEX (FLI) 10

FUELS IN THE NATIONAL FIRE-DANGER RATING SYSTEM 10

THE FIRE WEATHER OBSERVATION 17

THE FIRE WEATHER FORECAST 19

PUBLICATIONS CITED 21

APPENDIXES:

A. ABBREVIATIONS; GLOSSARY 23

B. SELECTION OF FUEL MODELS 29

C. SELECTION OF SLOPE CLASS 35

D. LIGHTNING RISK. 36

E. MAN-CAUSED RISK 41

F. INTERPRETATION OF THE OCCURRENCE INDEXES 48

G. INTERPRETATION OF THE BURNING INDEX 49

H. USING THE LIVE FUEL MOISTURE PREDICTION MODELS . . . 51

I. THE 10-HOUR TIMELAG FUEL MOISTURE 55

J. THE 10-DAY FIRE DANGER AND FIRE WEATHER RECORD . . . 57

PREFACE

At the time of this writing, the spring of 1977, the 1972 version of the National Fire-Danger Rating System (Deeming and others 1972) is being used by all Federal agencies and 35 State agencies charged with forest and rangeland fire protection. During the summer of 1976, data from more than 800 fire-danger rating stations were processed through the interactive computer program AFFIRMS (Helfman and others 1975; Deeming 1975; Straub 1975) and half again as much data were processed manually each day.

But things have changed since 1972. Knowledge of combustion physics, wildland fuels, and the factors that influence the occurrence of forest and rangeland fires is expanding. And experience with the 1972 NFDRS has highlighted problems in the System that need attention.

All of this was anticipated at the time the 1972 NFDRS was released for field use. Plans were made at that time for an update of the System in 1978 that would correct deficiencies and incorporate new research. That update is documented in this report.

This work was done under the direction of a technical committee chartered in 1974 by the Chief of the Forest Service. The NFDRS Technical Committee membership was of USDA Forest Service research and forest systems personnel, and fire managers from the Bureau of Land Management, and the States of Pennsylvania, North Carolina, and Oregon.

The results of this effort are presented in two publications. This publication covers basic instructions for applying and interpreting the NFDRS. A separate publication, Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System (Burgan and others 1977), is intended for those who do not utilize AFFIRMS. It contains the nomograms and directions for manually calculating fire-danger ratings.

Instructions covering the few procedural changes for AFFIRMS will be distributed to AFFIRMS users as amendments to the AFFIRMS User Guide (Helfman and others 1975).

UPDATING THE NATIONAL FIRE-DANGER RATING SYSTEM

The principal problem areas to be addressed in the updating effort were:

1. The need to improve the response of the NFDRS to drought.
2. The lack of sensitivity of the ratings, particularly in the lower fire-danger ranges.
3. The lack of response of the NFDRS ratings to changing day length.
4. The inadequate representation of fuels by the nine available fuel models.
5. The need to develop a fire occurrence index that would provide the fire manager with reliable information on fire incidence.
6. The need for a better way to assess the condition of the live fuels: grasses, forbs, and woody shrubs.
7. Three slope classes were not sufficient to properly describe the terrain in some areas of the West.

In addition to addressing these specific problems, a more general objective was to ncorporate the latest relevant developments in fire modeling, forest fuels, and fire ccurrence research. The following section tells briefly how these problems were olved. (See appendix A for definition of abbreviations and terms.)

Response to Drought

Because the largest fuel considered in the 1972 NFDRS has only a 100-hour moisture imelag, the NFDRS indexes and components are not influenced by extended periods of elow average precipitation. The initial problem was to determine the avenue by which ong-term drying affects fire behavior.

The most obvious response to long-term drying that affects fire behavior is the ecrease in moisture content of the live fuels--grasses, forbs, and the twigs and oliage of woody shrub species. In addition, dead fuels up to 6 inches in diameter 1,000-hour timelag class) that do respond to long-term drying were incorporated in hose fuel models where it was realistic to do so.

Sensitivity of Ratings

The problem has been solved by not restricting the burning index (BI), energy elease component (ERC), and spread component (SC) to 0 to 100 scales. The SC is umerically equal to the theoretical rate of spread in feet per minute; and the ERC is umerically equal to the available energy in Btu's per square foot divided by 25. The I has been scaled so that it equals 10 times the predicted flame length.

The results have been a fivefold increase in the sensitivity of the SC; the BI is hree times as sensitive; and the ERC is about twice as sensitive.

Fuel Models

In the 1972 NFDRS, the user is given a choice of nine fuel models. Many users feel that fuels in their areas are not adequately represented; others, on the other hand, are of the opinion that such a range of choices is not needed to rate fire danger.

The set of fuel models has been increased to 20. Twenty models should adequately represent the fuels that must be dealt with in the United States.

Fire Occurrence Models

Because of the dissimilarities of the causative firebrands and the fuels where the fires typically start, man-caused and lightning-caused fires are considered separately. The structure of the occurrence module has been modified with separate occurrence indexes for man-caused and lightning-caused fires.

The Man-Caused Fire Occurrence Index (MC)I)

The MCOI is derived from the man-caused risk (MCR) and the ignition component (IC) The MCR appears essentially the same as in the 1972 NFDRS. However, it incorporates factors derived from local fire and fire weather records that make the MCOI a much improved indicator of fire occurrence.

Lightning-Caused Fire Occurrence Index (LOI)

The lightning-caused fire occurrence index is derived from lightning risk (LR) and the IC. LR is based on a subjective assessment of lightning and thunderstorm activity and a factor calculated from local records of thunderstorms and lightning fires. The LR scaling factor, as it is called, will fit the predictions of the lightning fire occurrence model to local conditions.

Six lightning activity levels (LAL) are available to choose from. LAL's 1 through 5 are similar to those in the 1972 NFDRS, but the basis for selection has been expanded LAL 6 was added to flag emergency level lightning fire activity.

Seasonality of Ratings

The 1972 NFDRS tends to overrate fire danger during the early spring, late summer, and fall, particularly in Alaska and the more northern of the lower 48 States. The pro lem was to account for the seasonal and latitudinal variation of insolation and its effect on the moisture exchange processes.

To this end we have made several changes. Instead of using a simple average of the 24-hour maximum and minimum equilibrium moisture contents in calculating the 100-h TL and 1,000-h TL FM's, an average, weighted by day length, is used to characterize the "drying power" of the day. As the period of daylight shortens, the nighttime conditions are given increasing weight, thus promoting recovery in the predicted moisture content of the heavy fuels.

The fuel moisture analog (half-inch sticks) value is used for the calculation of 10-h TL FM and is now weighted into the calculation of the 1-h TL FM. The analog provides a straightforward solution because the seasonally induced effects are automatically integrated in the fuel stick response.

Insufficient Terrain Definition

In the 1972 NFDRS, three slope classes are used: 0-20 percent, 21-40 percent, an greater than 40 percent. This is not sufficient for mountainous areas where slopes up to 100 percent are commonly encountered. The number of slope classes has been increas to five, with 90 percent the midpoint of slope class 5.

PRINCIPLES OF THE NATIONAL FIRE-DANGER RATING SYSTEM

To use the NFDRS effectively, one must know what it will do and will not do. The basic principles of the NFDRS are as follows:

1. The NFDRS relates only to the potential of the initiating fire. An initiating fire is one that does not behave erratically; it spreads without spotting through continuous ground fuels. Crowning and spotting are not now addressed. However, experience with the NFDRS will enable users to identify the critical levels of fire danger when such behavior is highly probable.

2. The System only addresses those aspects of fire control strategy affected by fire occurrence and behavior. The concept of containment, as opposed to extinguishment, is basic because it allows us to limit the scope of the rating problem to the behavior potential of the headfire. Other aspects of the containment job such as accessibility, soil condition, and resistance to line construction must be evaluated by other means.

3. The ratings are relative, not absolute. Wherever possible, we have structured the component or index so that it is linearly related to the particular aspect of the fire problem being rated. Thus, when the value of a component or index doubles, the fire manager should expect a doubling of the rated activity relative to what has been recently observed. *The BI is an exception that will be addressed later.*

4. Fire danger is rated from a *worst case* approach. Fire weather is measured at the time of day when fire danger is normally the highest; and wherever possible, in the open at midslope on southerly or westerly exposures. This important principle must be understood if fire-danger ratings are to be properly interpreted.

What if a fire occurs before or after the peak of the burning period? Or at a location other than midslope on a southerly aspect? The odds are overwhelmingly against the behavior of a particular fire equaling or exceeding that indicated by the ratings. The fire behavior components computed for a day characterized by normal diurnal patterns of relative humidity, temperature, and wind *define the approximate upper limit of behavior.*

By chance, there will always be fires that exceed the indicators because one observation per day per 100,000 or more acres is a thin sample. Conditions more severe than those represented by the fire weather observation are sure to exist.

The term *average worst*, long heard among fire managers, was first used by Gisborne (1936) and Hayes (1944) to denote the *average* of fire-danger ratings computed from several sets of fire weather data. This average answered the need to combine several sets

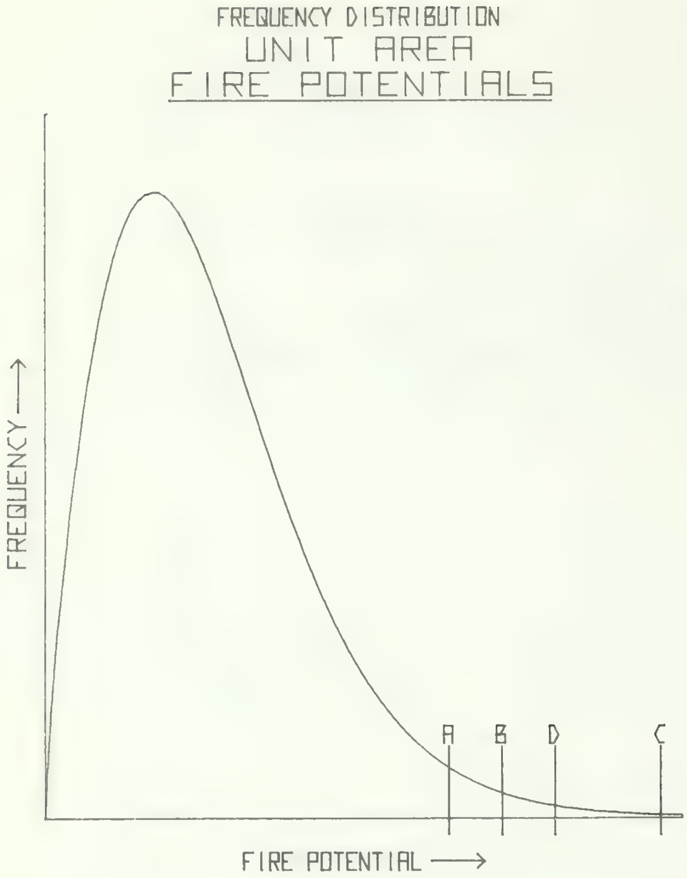

Figure 1.--Theoretical frequency distribution of unit area fire potentials for a 24-hour period. The behavior of fires started randomly over a fire-danger rating area without regard for time of day, slope position, or aspect would be distributed in a manner similar to this curve. Fire-danger stations A, B, and C would indicate relatively high potential because the data are collected in the afternoon on the more severe sites. (D is the average of A, B, and C.) The majority of fires, by far, will behave less severely than fire-danger data indicate.

of data into a single set that the decisionmaker could readily use. What does "average worst" actually mean? If one could compute a set of fire-danger ratings for every acre of a protection unit every half-hour, those ratings would be distributed approximately as in figure 1. Most of the ratings would indicate relatively low fire potential, skewing the distribution toward the low side.

Locate the ratings computed from data taken at three hypothetical fire weather stations A, B, and C at basic observation time. D is the average of A, B, and C, hence defines *average worst*, the level the fire manager would prepare for.

The area under the curve to the right of D represents the probability that a specific fire will burn under conditions more severe than the fire suppression organization is prepared for. A protection agency cannot afford to protect at the level indicated by C, so it must gamble that a fire will not occur under those conditions. Sometimes a fire does occur and the gamble does not pay off.

We do not know the probability of such an event happening. The probability is low however, because we rate fire danger for the worst possible conditions--on south or southwesterly aspects, and so on.

The main point is this: the NFDRS will not predict how every fire will behave. Other systems fill this need (Albini 1976b; Van Gelder[1]). The NFDRS is intended to provide guidance for short range planning. *It evaluates the near upper limit of the behavior of fires that might occur on a rating area during the rating period.*

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[1] Van Gelder, Randall J. Firecasting--the next generation of fire-danger rating? USDA For. Serv. Res. Note [in preparation]. Pac. Southwest For. and Range Exp. Stn., Berkeley, California.

STRUCTURE OF THE NATIONAL FIRE-DANGER RATING SYSTEM

The System (fig. 2) provides four indexes to aid in planning fire control activities. They are: the man-caused fire occurrence index (MCOI), the lightning-caused fire occurrence index (LOI), the burning index (BI), and the fire load index (FLI).

The MCOI is derived from the man-caused risk (MCR), an assessment of the status of man-caused fire sources in a rating area, and the ignition component (IC), an expression of the likelihood that a firebrand will cause a reportable fire.

The lightning-fire occurrence index (LOI) is similar in concept to the MCOI. It is derived from the IC and lightning risk (LR), an indicator of thunderstorm activity. Both OI's are interpretable in terms of expected numbers of fires on the rating area.

The BI is derived from the spread and energy release components (SC and ERC). The rate of fire spread and the energy released in the flaming zone, considered together, are the means of rating the difficulty of containment. The BI is linearly related to the length of flames at the head of the fire. It is calculated from the SC and ERC using the relationships originally developed by Byram for calculating flame length (Byram 1959, p. 82).

A measure of the difficulty of containing a single fire (the BI), combined with the probable number of fires as projected by the MCOI and LOI, produces a measure of the total potential fire containment job. This is the fire load index (FLI). The FLI is the ultimate index of the NFDRS; it integrates the risk, ignition, and fire behavior potentials as evaluated by the other indexes and components.

The risk ratings (LR and MCR), the fire occurrence ratings (LOI and MCOI), the ignitibility rating (IC), and the fire load index are expressed on scales of 0 to 100 just as in the 1972 NFDRS. The SC, ERC, and BI scales are open-ended; that is, no upper limits have been imposed.

1978 NATIONAL FIRE-DANGER RATING SYSTEM

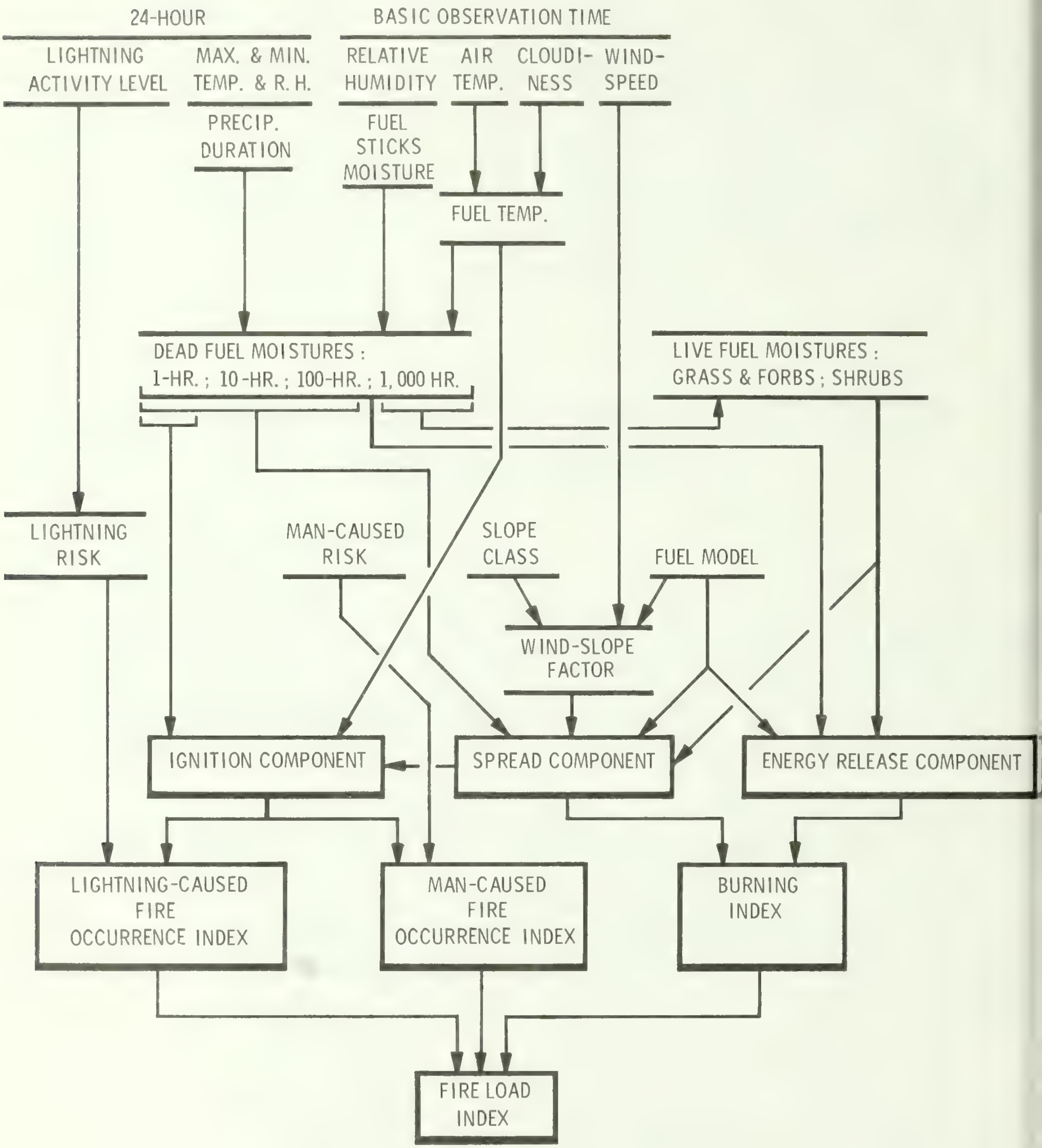

Figure 2.--Structure of the 1978 National Fire-Danger Rating System.

THE NATIONAL FIRE-DANGER RATING SYSTEM COMPONENTS

Risk and the IC, SC, and ERC are the foundation of the NFDRS. These components directly address the problems of integrating the effects of fuels--quantity, arrangement, fuel particle geometry and chemistry--fuel moisture, wind, topography and state of fire-starting agents. Because of their basic importance to the NFDRS, a closer look is warranted. The components can be subdivided into those that deal with fire behavior potential and those that deal with fire occurrence.

Fire Behavior Potential

To successfully rate fire danger, a realistic appraisal of the behavior potential of possible fires is essential. For control planning, the first consideration is rate of spread. The spread component is directed at this need.

A second basic consideration is the potential amount of energy that can be released in a passing fire. This is indicated by the energy release component.

Combined in the BI, these components provide an estimate of potential flame length and fireline intensity.

The Spread Component (SC)

The SC is based on a mathematical fire spread model developed at the Northern Forest Fire Laboratory (Rothermel 1972; Albini 1976a, 1976b). The spread model integrates the effect of wind, slope, and fuel bed and fuel particle properties to predict the forward rate of fire spread. The slope class and the fuel model (fuel model specifies the fuel particle and fuel bed characteristics) are constants in the calculation of the SC. The daily variations of SC are caused by the changes in the wind and moisture contents of the live fuels and the dead fuel timelag classes of 1, 10, and 100 h.

The Energy Release Component (ERC)

The ERC is based on the estimated potential available energy released per unit area in the flaming zone of the fire. The ERC is dependent on the same fuel characteristics as the SC; loading, compaction, particle size (fineness), heat of combustion, and mineral content. The day-to-day variations of the ERC are caused by changes in the moisture contents of the various fuel classes, including the 1,000-h TL class. The ERC is derived from predictions of (1) the rate of heat release per unit area during flaming combustion, and (2) the duration of flaming.

Fire Occurrence

For effective fire suppression and prevention one must estimate not only the behavior of fires *that might occur*, but also the number of fires to expect. In the NFDRS, the MCOI and LOI indicate the expected level of fire incidence.

The occurrence indexes are derived from assessments of the ignitibility of fine fuels and prevalence of ignition sources (firebrands). The IC is a measure of ignitibility. The two risk components, LR and MCR, are evaluations of the status of lightning and the fire-causing activities of man. Let us look at each in more detail.

The Ignition Component (IC)

The IC is related to the probability of a firebrand producing a fire that will require suppression action. Ignition occurs in four phases: (1) the firebrand comes in contact with the dead fine fuel; (2) the moisture in the fuel particle is driven off; (3) the temperature of the fuel particle is raised to the point where pyrolysis begins--200° to 250°C (390° to 480°F); and (4) ignition occurs when the fuel and the pyrolytic gases are heated to approximately 320°C (610°F).

The probability that a firebrand will ignite fuels is mainly a function of (1) dead fine fuel moisture content--(1-h TL FM); (2) dead fine fuel temperature; (3) the surface area-to-volume ratio (fineness) of the fuel elements; (4) the compactness of the fuel bed; and (5) firebrand characteristics such as temperature, rate of heat released, the length of time it will burn, and whether it is glowing or flaming. For fire-danger rating purposes only the variability of the first two are considered.

The moisture content of the dead component of the fine fuel (1-h TL FM) is governe primarily by the temperature and relative humidity of the air immediately in contact with the fuel particle. In calculating the 1-h TL FM, the temperature and relative humidity measured in the instrument shelter are adjusted to fuel level. The extent of the adjustment is dependent upon the amount of cloudiness (Fosberg and Deeming 1971; Haltiner 1975).

The higher the initial temperature of the fuel, the easier it is to raise the temperature of the fuel particle to the kindling point. Just as in the calculation of the 1-h TL FM, a correction is made to the instrument shelter temperature to approximat the fuel temperature.

The IC must also consider the probability that a successful ignition will evolve into a fire requiring suppression action. Work in the northeastern and southeastern United States has shown that the number of man-caused fires increases as the potential rate of spread increases (Crosby 1954; Haines and others 1970). With the incorporation of the spread component in the 1978 NFDRS ignition component, its validity has been greatly improved.

Lightning Risk (LR)

The LR has been designed to account for more than just the quantity of cloud-to-ground lightning, as was done in the 1972 NFDRS.

Characteristics of regional storms affect the "efficiency" of lightning as a fire starter. For instance, West Coast and Great Plains thunderstorms are "wetter" than those of the Southwest and the Central and Northern Rockies. Another example: the frequency of "hot" cloud-to-ground discharges capable of starting fires appears to be greater in Alaskan storms than in any others.

Local and regional fuels also affect lightning efficiency. The finer the fuel particles and the "fluffier" the fuel bed, the more susceptible the fuel is to ignition by a lightning stroke. For instance, in the Northern Rockies, more fires occur per uni area in ponderosa pine than in any other forest cover type (Barrows 1951; Barrows and others[2]).

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[2] Barrows, J. S., D. V. Sandberg, and J. D. Hart. 1977. Lightning fires in Northern Rocky Mountain forests. Final Rep. Coop. Agreement 16-44-CA, Colorado State Univ. and Intermt. For. and Range Exp. Stn., 210 p. Unpublished report on file at the North. For. Fire Lab., Missoula, Mont.

To measure all regional factors would be an impossible task. Instead, we introduced a statistic derived from local records of thunderstorm and lightning-caused fires, the *lightning risk scaling factor*. Details for its derivation are included in appendix D.

The LR is derived from forecasts or observations of thunderstorm activity (lightning activity level--LAL). The LR associated with an LAL is then "fitted" to local experience by applying the LR scaling factor.

A sixth lightning activity level has been added to those introduced in the 1972 NFDRS. It serves as a "red flag" to denote those extremely dangerous situations that occasionally occur in Alaska and the western States. When an LAL 6 is specified, the LOI is automatically set to 100.

Based on current data, the NFDRS will continue to assume that 25 percent of all lightning-caused fires remain undetected for at least 24 hours.

Man-Caused Risk (MCR)

Procedures for estimating man-caused risk remain similar to those used in the 1972 NFDRS. However, incorporation of a statistic derived from local records of fire weather and man-caused fires has greatly increased the accuracy of fire occurrence prediction (appendix F).

No objective means have been developed for determining the MCR. As in the 1972 NFDRS, it continues to be based on the local fire manager's estimates of the status of fire-causing agents. The scheme is reasonably simple. On a scale of 1 through 5 (*daily activity level*), a rating is assigned to activities that have been important sources (*risk sources*) of man-caused fires in the rating area. The rating scale is calibrated to the level of activity normal for *that day of the week*. If a particular risk source is less active than what is normal for that day of the week, a "None" or "Low" daily activity level may be assigned; if it is more active, a "High" or "Extreme" daily activity level may be assigned.

The contribution that a particular risk source makes to the final MCR value is weighted according to the proportion of the historical man-caused fires occurring on that day of the week that are attributable to that risk source (*risk source ratio*).

The principal risk sources for the fire season are identified by analyzing fire occurrence records.

Although daily activity levels may be similar, actual risk may vary greatly among protection units. Firebrands and fuels differ from one area to another. Also, fire prevention programs and the attitudes of the populace toward fire differ. We deal with these differences as we did with lightning risk: develop a statistic that can account for local factors. The derivation of the *man-caused risk scaling factor* is covered in appendix E.

The procedure for evaluating MCR can be partitioned into two phases. Phase 1 involves analyzing historical fire weather and fire occurrence records to (1) identify risk sources; (2) determine risk source ratios, and (3) derive the MCR scaling factor.

Phase 2 is those tasks that must be done daily. It consists of (1) assigning a daily activity level to each risk source and (2) computing the MCR.

Appendix E covers the procedures in detail and contains worked examples.

FIRE LOAD INDEX (FLI)

Stated again, the FLI is the culminating index of the NFDRS. It is designed to combine the projections of fire occurrence and behavior into a single number that can be related to the total fire control job.

Because fire managers have not agreed on a common denominator for measuring the total job, the equation for calculating the FLI has been developed intuitively. The task of attaching meaning to the FLI has been left to the users. They will have to determine the relationship between the FLI and whatever measure of the total fire control effort they choose.

The FLI ranges over a scale of 0 to 100. A high FLI can be caused by a projection of high fire incidence (LOI + MCOI) *or* severe fire behavior. By itself, the FLI does not tell much about the nature of the fire management problem. To get a complete picture, one has to examine the components and indexes that are the basis for the FLI.

The fire load index is designed as the primary manning index for a major administrative unit such as a county or National Forest. However, the mix of men, ground equipment, and aircraft needed are best indicated by the BI, SC, and ERC.

FUELS IN THE NATIONAL FIRE-DANGER RATING SYSTEM

Classification of Wildland Fuels

Fire danger varies from day to day with changes in risk, wind, and moisture content of fuels. Moisture contents of dead fuels are controlled by environmental factors relative humidity, precipitation, and temperature. Moisture levels within living plant are primarily controlled by life processes. This distinction is the basis for the firs major divisions in the NFDRS fuel classification system--dead and live fuels.

Dead fuels are assigned to subclasses according to the speed or timelag (Lancaster 1970) with which the moisture content of the individual fuel particle responds to precipitation, relative humidity, and temperature. The shorter the timelag, the more responsive the fuel. In the 1972 NFDRS, three dead fuel classes were included: 1-, 10- and 100-hour timelag. For 1978, a fourth class was added--that of the 1,000-hour timelag fuel. The 1978 NFDRS timelag classes for dead fuels are shown in table 1.

Table 1.--*NFDRS dead fuel classes*

Timelag class	Fuel	
	Roundwood (diameter)	Litter (depth)
	Inches	
1-hour (0-2 hours)	To 1/4	To 1/4
10-hour (2-20 hours)	1/4 to 1	1/4 to 1
100-hour (20-200 hours)	> 1 to 3	> 1 to 4
1,000-hour (200-2,000 hours)	> 3 to 8	> 4 to 12

Two major classes of living fuels are recognized: (1) grasses and other herbaceous lants and (2) shrubs, specifically the twigs and foliage. The herbaceous plants are ubdivided into annuals and perennials. Annual herbaceous plants are shallow rooted nd are the first to be affected by drought. The perennials are next, and shrubs, which re the deepest rooted, are the least affected. From the phenological aspect, annuals omplete their growth cycle well within a normal growing season. They sprout, grow, roduce seed, and die before the first freeze normally occurs. Perennials, on the other and, normally stay green throughout the growing season and do not cure completely until emperatures in the fall get too low to sustain growth.

uel Models

The concept of fuel models was first introduced in the 1972 NFDRS (Deeming and thers 1972). That publication, and another by Deeming and Brown (1975), explained the ole of fuel models. To review briefly, fuel models were devised as a means for organzing fuels data for input into Rothermel's mathematical fire spread model. The fire pread model requires fuel bed properties such as compactness and loadings by classes f living and dead fuels; and fuel particle properties such as density, geometry, heat ontent, and mineral content.

Before selecting the fuel and cover types for the fuel models we needed to decide ow precise the models had to be to achieve the objectives of fire danger rating. Reall that the principal objective of the NFDRS is to produce information for presuppresion planning. The target is large--a fire-danger rating area may be tens of thousands f acres in size. And the period is long--from several hours to 24 hours. Because ind, fuel moisture, and slope vary so much within such a large area, these factors are ore likely to limit the accuracy of the fire-danger projections than the lack of preision in the fuel models.

Since 1972, more has been learned about the physical properties of fuels through research and experience. For 1978, we have increased the number of fuel models from 9 to 20 and have improved the descriptors of the existing models. To make the models more responsive to drought, we have added live fuels and the 1,000-hour timelag fuels where warranted. Only one of the original nine models has been deleted--fuel model F. The original F model has been replaced with a model representing intermediate brush (mature chamise and mixed chaparral less than 6 feet tall). With the exception of the F model, the original nine models have retained the alphabetical designators assigned in the 1972 NFDRS.

Table 2.--*Fuel models for Climate Class 1*

Fuel moisture:

1-h	10-h	100-h	1000-h	Herb	Woody
2%	4%	6%	7%	Cured	65%

Wind: 20 mi/h, 20 ft (32 km/h, 6 m)

Slope class: 1

Letter desig.	Fuel model	BI	SC	ERC
Grass type fuels				
A	Annual grass and forbs	102	570	4
Brush type fuels				
T	Sagebrush grass	116	133	21

Table 3.--*Fuel models for Climate Class 2*

Fuel moisture:

1-h	10-h	100-h	1000-h	Herb	Woody
3%	5%	7%	9%	Cured	70%

Wind: 20 mi/h, 20 ft (32 km/h, 6 m)

Slope class: 1

Letter desig.	Fuel model	BI	SC	ERC
Grass type fuels				
A	Annual grass	89	489	3
L	Perennial grass	96	300	6
S	Alaskan tundra	56	24	24
Brush type fuels				
T	Sagebrush grass	103	118	18
F	Inter. brush	93	54	32
B	Mature chaparral	172	97	69
Timber type fuels				
C	Open timber/grass	69	45	20

In tables 2, 3, 4, and 5, the fuel models are grouped according to the climate of the areas where they are most likely to apply. The BI, SC, and ERC were computed and tabulated for fairly severe fuel moisture conditions for those climates. For all four groups, the 20-ft windspeed was held constant at 20 mi/h. Slope class 1 was used across the board. *For an explanation of the climate classes, see appendix H.*

The fuel models are grouped in this manner for easy comparison of performance. For example, it would be unrealistic and misleading to compare the performance of the western annual grass fuel model, which should be used only in the desert southwest (climate class 1), to the southern rough fuel model, which is applicable only in the southeast (climate class 3).

Descriptions of the fuel models and instructions for selecting an appropriate fuel model are included in appendix B.

Table 4.--*Fuel models for Climate Class 3*

Fuel moisture:

1-h	10-h	100-h	1000-h	Herb	Woody
4%	6%	8%	11%	65%	75%

Wind: 20 mi/h, 20 ft
(32 km/h, 6 m)

Letter desig.	Fuel model	BI	SC	ERC
	Grass type fuels			
L	Perennial grass	57	178	3
N	Sawgrass	138	167	25
	Brush type fuels			
O	Pocosin	174	99	69
	Timber type fuels			
U	Western, long-needled conifer	55	16	36
P	Southern plantation	48	14	29
D	Southern rough	125	68	48
H	Closed, short-needle conifer (normal dead)	39	8	33
G	Closed, short-needle conifer (heavy dead)	95	30	61
Q	Alaskan black spruce	124	59	56
E	Hardwoods (winter)	65	29	27
R	Hardwoods (summer)	26	6	18
	Slash type fuels			
K	Light slash	89	23	68
J	Medium slash	197	44	201
I	Heavy slash	301	65	343

Table 5.--*Fuel models for Climate Class 4*

Fuel moisture:

1-h	10-h	100-h	1000-h	Herb	Woody
5%	7%	9%	13%	65%	80%

Wind: 20 mi/h, 20 ft (32 km/h, 6 m)

Slope class: 1

Letter desig.	Fuel model	BI	SC	ERC
	Timber type fuels			
H	Closed, short-needle conifer (normal dead)	35	7	28
G	Closed, short-needle conifer (heavy dead)	85	27	52
	Slash type fuels			
K	Light slash	80	21	60
J	Medium slash	178	40	179
I	Heavy slash	272	59	304

Fuel Moisture

Live Fuel Moisture Models

One of the more important changes introduced in the 1978 NFDRS is a method to predict seasonal changes in moisture content of annual or perennial herbaceous vegetation and the foliage and small twigs of woody shrubs.

In the 1972 NFDRS, the state of the live lesser fuels (grasses and forbs) was denoted by estimating the live proportion of the fine fuel complex. These estimates were made by directly sampling the fine fuels along a permanent transect. Moisture content of live, woody fuels was estimated by selecting one of three condition states or stages of woody plant development--rapid growth, maturing, or drought stage.

The major difficulty with these approaches is the inconsistency among observers selecting sampling sites and taking measurements. Assuming accurate measurements, th data may change drastically with transect location. Thus, we need to develop a metho that would provide consistent, broadscale estimates of the moisture contents of the live fuel components.

The need to improve the response of the NFDRS rating to drought substantially added to the importance of correctly specifying moisture values for live fuels. Rath than provide an auxiliary drought index, the preferred solution was to cause the rati to respond to the increased flammability of live plants and heavy dead fuels due to drought. Adding the 1,000-hour timelag class of dead fuels was an obvious advance.

Table 6.--*Minimum percent moisture for live fuels*

Type of season	Grasses and forbs		Shrubs, twigs, and foliage
	Annuals	Perennials	
Wet	∿30 (Late cure)	>80	>110
Normal	<30 (Normal cure)	50-80	80-110
Dry	<30 (Early cure)	<50	50-80

The first live fuel moisture models were developed by R. C. Rothermel (Northern Forest Fire Laboratory, manuscript in preparation). He derived empirical relationships between the moisture contents of vegetation sampled at several elevations near Missoula, Montana, and the Keetch-Byram drought index (Keetch and Byram 1968). The authors adapted Rothermel's work for the NFDRS, substituting the 1,000-h TL FM for the drought index. (That is why the 1,000-h TL FM must be calculated even for fuel models that do not include 1,000-h TL fuels.)

The live fuel models were calibrated to produce reasonable fuel moisture values for both herbaceous and woody vegetation. The performance objectives for the live fuel models are summarized in table 6.

The user has considerable control over the responses of the live fuel moisture models through his selection of climate class and the type of lesser vegetation--annual or perennial.

Climate classes adjust the response of the live fuel moisture prediction models to environmental conditions. Plants native to high precipitation areas react differently to a rainfall anomaly of a given magnitude than do plants native to arid areas.

Designating the lesser vegetation as annual or perennial is extremely important. The live fuel moisture model will predict faster drying and curing rates for annuals than for perennials.

Instructions for selecting the climate class and using the live fuel moisture models are covered in appendix H.

Dead Fuel Moisture Models

The methods for calculating the moisture content of the dead fuel classes are essentially the same as those used in the 1972 NFDRS and are based on the similar theory and procedures (Fosberg 1970 and 1971; Fosberg and Deeming 1971). The key parameters are the equilibrium moisture content (U.S. Forest Products Laboratory 1974) and precipitation duration (Fosberg 1972).

The 1,000-h TL FM model is a simple extension of the 100-h TL FM model. The drying (or wetting) factor must be calculated for each 24 hours, using the maximum and minimum temperatures and relative humidities, and the precipitation duration. The 1,000-h TL FM is calculated from a running 7-day average of the daily factors and the 1,000-h TL FM at the beginning of the 7-day period.

Refinements have been made to the 100-h TL FM model to simplify the calculations and adjust its response to precipitation and changes in day length. The results are lower values in midsummer and higher values in midwinter than you would obtain using the 1972 method.

The new method of calculating the 10-h TL FM is more complex than that used in the 1972 NFDRS. The answer is dependent upon the previous day's value of the 10-h TL FM, the 24-hour extremes of temperatures, and relative humidity and precipitation. Precipitation duration must still be considered in two periods--the first 16 hours and the last 8 hours of the 24 hours between observations.

To account for day length and the lingering influence of wet soil on the ground fuels after rain, the 1-h TL FM model has been changed. The solution was borrowed from the Wildland Fire-Danger Rating System used in California from 1958 to 1972 (U.S. Department of Agriculture, Forest Service 1958).

In the new model, the 1-h TL FM is a weighted average of the fuel stick moisture content and the equilibrium moisture content calculated from the observation time temperature and relative humidity. The fuel sticks integrate the effects of day length and cloudiness. Because they are exposed near the ground, the sticks reflect the influence of soil moisture on the relative humidity at ground level. During extended dry periods in midsummer, the results of the 1-h TL FM calculation will be very close to those obtained using the 1972 method.

THE FIRE WEATHER OBSERVATION

The recording of weather data should be started at least 4 weeks before the fire season. This lead time is needed to stabilize the predictions of 1,000-h TL and live fuel moistures. Values for the 100-h TL FM and the 1,000-h TL FM at the time observations are begun are normally 30 percent moisture content (McCammon 1976). But, a lower or higher starting value can be used if you have information from comparable sites in the vicinity. Accurate starting values are not needed, however, if the 4-week rule is adhered to. After 4 weeks the predictions will be close to the real answers regardless of the starting value.

The NFDRS requires more weather information than fire-danger rating systems that predate 1972. This includes 24-hour maximum and minimum relative humidities and temperatures, and rainfall duration.

Estimates of the beginning and ending times and the duration of rainfall are considered adequate. The 24-hour extreme value for temperature and relative humidity can be obtained from a hygrothermograph. If a hygrothermograph is not available, the maximum and minimum relative humidities can be estimated to acceptable accuracy when the 24-hour temperature extremes are known (Burgan and others 1977, appendix A).

Fuel moisture sticks should be used to determine the 10-h TL FM. Because the dry stick weight changes over time, a correction for stick age must be applied (appendix I). For those who do not use fuel moisture sticks, less reliable methods of estimating the 10-h TL FM are available. The AFFIRMS program can be instructed to calculate the 10-h TL FM from maximum and minimum relative humidities and temperatures, and rainfall durations. Instructions and nomograms for the alternate method of estimating the 10-h TL FM are contained in *Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System* (Burgan and others 1977, appendix B).

Regarding the condition of live fuels--the user must record when greenup occurs, whether it is the initial spring flush or a midseason event as sometimes occurs in arid areas. It is also necessary to indicate when the fine fuels have completely cured (appendix H).

The following list summarizes inputs into the NFDRS. These data should be recorded on the 10-day Fire Danger and Fire Weather Record (appendix J), or on the AFFIRMS recording form.

Station number
Station elevation
Fuel model (appendix B)
Herbaceous vegetation--annual or perennial (appendix H)
Slope class (appendix C)
Date (year, month, day)
State of weather
Herbaceous vegetation condition (appendix H)
Dry and wet bulb temperatures
Lightning risk (appendix D)
Man-caused risk (appendix E)
Windspeed (10-minute average)
Wind direction
Precipitation kind
Precipitation amount
Precipitation duration
Precipitation, beginning and ending times
Lightning activity level (appendix D)
24-hour maximum and minimum temperatures
24-hour maximum and minimum relative humidities
10-hour timelag fuel moisture (appendix I)

The information on the cover of the National Weather Service Form 10-Day Fire Danger and Fire Weather Record, should be reviewed carefully. It covers the proper procedures for taking a fire weather observation.

The fire weather station should be set up in strict accordance with the directions outlined by Fischer and Hardy (1976). An inexpensive triple-beam balance can be substituted for the fuel moisture scales. If a hygrothermograph is not available, use a maximum/minimum thermometer.

THE FIRE WEATHER FORECAST

The fire weather forecaster has been asked to predict the values of those weather elements that will govern the fire danger at a future time, normally the next afternoon. Those predictions should be processed through the National Fire-Danger Rating System to obtain the necessary components and indexes. If you subscribe to the AFFIRMS program, this is done automatically. You can retrieve the fire-danger ratings computed from the the forecasted elements directly from the computer. If you calculate the fire-danger ratings manually, you will have to maintain a set of 10-day fire danger and weather records for recording and processing the fire weather forecast. The procedures will be identical to those followed in calculating the fire-danger ratings from observed weather data, with one exception. If the fire weather forecaster does not predict the 10-h TL FM directly, you will have to make the calculation using the manual procedure (Burgan and others 1977, appendix B) *even if you use fuel sticks*.

A file of the fire danger and fire weather recording forms used for processing the fire weather forecast will provide you with the necessary data for verifying the adequacy of your fire weather service.

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APPENDIX A

ABBREVIATIONS

BI - Burning index
ERC - Energy release component
FLI - Fire load index
IC - Ignition component
LAL - Lightning activity level
LOI - Lightning-caused fire occurrence index
LR - Lightning risk
MCOI - Man-caused fire occurrence index
MCR - Man-caused risk
NFDRS - National Fire-Danger Rating System
SC - Spread component
TL - Timelag
1-h TL FM - 1-hour timelag fuel moisture content
10-h TL FM - 10-hour timelag fuel moisture content
100-h TL FM - 100-hour timelag fuel moisture content
1,000-h TL FM - 1,000-hour timelag fuel moisture content

GLOSSARY

AMBIENT.--Surrounding, enveloping conditions. As it pertains to weather at the earth's surface, the conditions measured in the instrument shelter are considered ambient.

ANALOG.--See fuel moisture analog.

ANNUAL.--A plant that lives for one growing season, starting from a seed each year.

AVERAGE RELATIVE HUMIDITY.--The arithmetic average of the maximum and minimum relative humidities measured at a fire-danger station from one basic observation time to the next.

AVERAGE TEMPERATURE.--The arithmetic average of the maximum and minimum dry-bulb temperatures measured at a fire-danger station from one basic observation time to the next.

BASE AREA.--An area representative of the major fire problem on a protection unit. From the base area, the base fuel model and slope class are chosen.

BASE FUEL MODEL.--The fuel model that best represents the fuels on the base area.

BASE OBSERVATION TIME.--The time established to take the fire-danger observation. It should be at that time of day when the fire danger is normally the highest.

BOUNDARY LAYER.--The air in immediate contact with a fuel element.

BOUNDARY CONDITIONS.--The temperature and relative humidity of the boundary layer.

BOUNDARY VALUE.--The EMC commensurate with the boundary conditions and precipitation events of the preceding 24 hours.

BRUSH.--Scrub vegetation and stands of tree species that do not produce merchantable timber. (NOT a synonym for slash.)

BURNING INDEX (BI).--A number related to the contribution of fire behavior to the effort of containing a fire.

CONTAINMENT.--The completion of a control line around a fire and any associated spot fires which can reasonably be expected to check the fire's spread.

CONTROL.--The completion of a control line around a fire and any associated spot fires, which can reasonably be expected to hold under foreseeable conditions. Control implies that the line has been burned out and all hot spots that threaten the line have been eliminated.

DAILY ACTIVITY LEVEL (DAL).--A subjective estimate of the status of a man-caused fire risk source relative to what is normally experienced on that day of the week. Five activity levels are defined: None, Low, Normal, High, and Extreme.

DEAD FUELS.--Naturally occurring fuels whose moisture content is governed by relative humidity and precipitation.

DEW POINT.--The temperature at which a parcel of air being cooled reaches saturation (100 percent relative humidity).

DIURNAL.--Pertains to daily cycles of temperature, relative humidity, and wind.

DROUGHT.--A period characterized by a serious moisture deficiency, extensive in area and time.

DRY-BULB TEMPERATURE.--The temperature of the air.

DUFF.--The partially decomposed organic material of the forest floor that lies beneath the freshly fallen twigs, needles, and leaves. (The F and H layers of the forest floor.)

EMC.--See equilibrium moisture content.

ENERGY RELEASE COMPONENT (ERC).--A number related to the available energy (Btu) per unit area (square foot) within the flaming front at the head of a fire.

EXPECTED NUMBER OF FIRES.--The number of fires that will occur *on the average* over numerous days with the same LOI or MCOI. In probability terminology, "expected" means the average of the results of a large number of trials made under identical circumstances.

EQUILIBRIUM MOISTURE CONTENT (EMC).--The moisture content that a fuel particle will attain if exposed for an infinite period in an environment of specified constant temperature and humidity. When a fuel particle has reached its EMC, the net exchange of moisture between it and its environment is zero.

EXTINCTION MOISTURE CONTENT.--The fuel moisture content, weighted over all the fuel classes, at which the fire will not spread.

FINE FUELS.--The complex of living and dead herbaceous plants and dead woody plant materials less than one-fourth inch in diameter.

FINE FUEL MOISTURE (FFM).--An adjustment to the 1-h TL FM that compensates for the presence of living plant material and the moisture content of that material. The FFM is used in the manual calculation of fire-danger ratings. It replaces the 1-h TL FM and the herbaceous fuel moisture.

FIREBRAND.--Any source of heat, natural or manmade, that is capable of igniting natural fuels.

FIRE-DANGER RATING AREA.--A geographical area within which the fire danger can be assumed to be uniform. It is relatively homogeneous in climate, fuels, and topography.

FIRELINE INTENSITY.--The rate of heat release per unit length of fire front. The most commonly used units in current fire literature are Btu/sec/ft.

FIRE LOAD INDEX (FLI).--A rating of the maximum effort required to contain all probable fires occurring within a rating area during the rating period.

FLAMING FRONT.--That zone of a moving fire where the combustion is primarily flaming. Behind the flaming front the combustion is primarily glowing or involves the burning out of larger fuels (greater than about 3 inches in diameter).

FORB.--A nongrasslike herbaceous plant.

FORECAST AREA.--The geographical area for which a fire weather forecast is specified.

FUEL CLASS.--A group of fuels possessing common characteristics. In the NFDR, dead fuels are grouped according to their timelag (1-, 10-, 100-, and 1,000-h TL). And living fuels are grouped by whether they are herbaceous (annual or perennial) or woody.

FUEL MODEL.--A simulated fuel complex for which all the fuel descriptors required by the mathematical fire spread model have been specified.

FUEL MOISTURE (FM).--See fuel moisture content.

FUEL MOISTURE ANALOG.--A device that emulates the moisture response of specific classes of dead fuels. Examples are basswood slats that represent the 1-h TL fuels and half-inch ponderosa pine dowels that represent the 10-h TL fuels. An analog may also be constructed of inorganic materials.

FUEL MOISTURE CONTENT (ALSO FUEL MOISTURE) (FM).--The water content of a fuel particle expressed as a percent of the ovendry weight of the fuel particle.

HERB.--A plant that does not develop woody, persistent tissue but is relatively soft or succulent and sprouts from the base (perennials) or develops from seed (annuals) each year. Included are grasses, forbs, and ferns.

HERBACEOUS FUELS.--Undecomposed material, living or dead, derived from herbaceous plants.

HERBACEOUS VEGETATION MOISTURE CONTENT.--The water content of a live herbaceous plant expressed as a percent of the ovendry weight of the plant.

HOLDOVER FIRES (ALSO SLEEPER FIRES).--Fires set by lightning but not discovered during the first burning period. In the NFDRS it is assumed that 25 percent of the fires are not discovered until succeeding burning periods.

HUMIDITY.--A measure of the water-vapor content of the air.

IGNITION COMPONENT (IC).--A rating of the probability that a firebrand will cause a fire requiring suppression action.

INITIATING FIRE.--A fire that has recently started and is not crowning or spotting

INSOLATION.--Solar radiation received at the earth's surface.

INSTRUMENT SHELTER (ALSO THERMOSCREEN).--A naturally or artificially ventilated structure used to shield temperature-measuring instruments from direct sunshine and precipitation.

LESSER LIVE FUELS.--Grasses and forbs; low nonwoody plants, annual and perennial.

LIGHTNING ACTIVITY LEVEL (LAL).--A numerical rating of 1 to 6, keyed to the start of thunderstorms and the frequency and character of cloud-to-ground lightning, forecasted or observed on a rating area during the rating period.

LIGHTNING FIRE OCCURRENCE INDEX (LOI).--A numerical rating of the potential occurrence of lightning-caused fires.

LIGHTNING RISK (LR).--A number related to the expected number of cloud-to-ground lightning discharges capable of starting fires that a rating area will be exposed to during the rating period.

LIGHTNING RISK SCALING FACTOR.--A factor derived from local thunderstorm and lightning-caused fire records that adjusts the predictions of the basic lightning fire occurrence model to local experience. It accounts for factors not addressed directly by the model such as susceptibility of local fuels to ignition by lightning, fuel continuity, topography, and regional characteristics of thunderstorms.

LITTER.--The top layer of the forest floor, typically composed of loose debris such as branches, twigs, and recently fallen leaves or needles; little altered in structure by decomposition. (The L layer of the forest floor.)

LIVING FUELS.--Naturally occurring fuels whose moisture content is controlled by physiological processes within the living plant. The NFDRS considers only herbaceous plants and woody plant material small enough (leaves and needles, and twigs) to be consumed in the flaming front of a fire.

MAN-CAUSED RISK.--A number related to the expected number of man-produced firebrands capable of starting fires that a rating area will be exposed to during the rating period.

MAN-CAUSED RISK SCALING FACTOR.--A number relating man-caused fire incidence to the IC on a rating area. The factor is a statistic based on 3 to 5 years of fire occurrence and fire weather data that adjusts the prediction of the basic man-caused fire occurrence model to fit local experience.

MOISTURE OF EXTINCTION.--See extinction moisture content.

NORMALIZATION.--The process of bringing into accord with a norm or standard.

1-HOUR TIMELAG FUELS.--Fuels consisting of dead herbaceous plants and roundwood less than one-fourth inch in diameter. Also included is the uppermost layer of litter on the forest floor.

1-HOUR TIMELAG FUEL MOISTURE (1-h TL FM).--The moisture content of the 1-hour timelag fuels.

100-HOUR TIMELAG FUELS.--Dead fuels consisting of roundwood in the size range of 1 to 3 inches in diameter and, very roughly, the forest floor from three-fourths inch to 4 inches below the surface.

100-HOUR TIMELAG FUEL MOISTURE (100-h TL FM). The moisture content of the 100-hour timelag fuels.

1,000-HOUR TIMELAG FUELS.--Dead fuels consisting of roundwood 3 to 8 inches in diameter or the layer of the forest floor more than about 4 inches below the surface, or both.

1,000-HOUR TIMELAG FUEL MOISTURE (1,000-h TL FM).--The moisture content of the 1,000-hour timelag fuels.

PARTIAL RISK.--The contribution of a specific source to the man-caused risk. The partial risk is derived from the daily activity level assigned a risk source and its risk source ratio.

PERENNIAL.--A plant that lives for more than two growing seasons. For fire-danger rating purposes, biennial plants are classed with perennials.

PRECIPITATION.--Any or all the forms of atmospheric water, liquid or solid, that reach the ground. (Usually measured to the nearest one-hundredth of an inch.)

PRECIPITATION DURATION.--The time, in hours and fraction of hours, that a precipitation event lasts. More precisely, for fire-danger rating purposes, it is the length of time that fuels are subjected to liquid water during the day.

PROBABILITY.--A numerical rating on a scale of 0 to 1 that a specific event will occur. A "1" translates to perfect certainty that the event will occur; a "0" that it will not.

RATING AREA.-See fire-danger rating area.

RATING PERIOD.--The period of time for which a fire-danger rating value is considered representative. Normally it is the calendar day, midnight to midnight.

RELATIVE HUMIDITY (RH).--The ratio of the actual amount of water vapor in the air to the amount necessary to saturate the air at that temperature and pressure. It is expressed as a percentage.

RESIDENCE TIME.--(1) The time required for the flaming zone of a fire to pass a stationary point; (2) the width of the flaming zone divided by the rate of spread of the fire.

RISK SOURCE.--An identifiable human activity that historically has been a major cause of wildfires on a protection unit. It is one of the eight general causes listed on the standard fire report.

RISK SOURCE RATIO.--The portion of the man-caused fires that have occurred on a protection unit chargeable to a specific risk source. A risk source ratio is calculated for each day of the week for each risk source.

ROUNDWOOD.--Boles, stems, or limbs of woody material; that portion of the dead wildland fuels which are roughly cylindrical in shape.

SHRUB.--A woody perennial plant differing from a perennial herb by its persistent and woody stem; and from a tree by its low stature and habit of branching from the base.

SLASH.--Branches, bark, tops, cull logs, uprooted stumps, and broken or uprooted trees left on the ground after logging; also debris resulting from thinnings or wind.

SLOPE.--Rise or fall (in feet) per 100 feet of horizontal measurement, expressed as a percentage.

SLOPE CLASS.--A code designating the most common slope in the base area. There are five classes: 0-25, 26-40, 41-55, 56-75, and greater than 75 percent.

SURFACE AREA-TO-VOLUME RATIO.--The ratio of the area of the surface of a fuel particle (square feet) to its volume (cubic feet). The higher the ratio, the "finer" the particle; for example, for grasses this ratio ranges above 2,000; for a half-inch fuel moisture stick it is 109.

SPREAD COMPONENT (SC).--A rating of the forward rate of spread of a head fire.

STANDARD DRYING DAY.--A day producing the same net drying as a 24-hour period where the dry bulb temperature is maintained at 80° F and the relative humidity at 20 percent.

STATE OF WEATHER.--A code entered in column 2 of the 10-Day Fire Danger Weather Record Form that indicates the amount of cloud cover, kind of precipitation, and/or restrictions to visibility at the fire-danger station at basic observation time.

10-HOUR TIMELAG FUELS.--Dead fuels consisting of roundwood one-fourth to 1 inch in diameter and, very roughly, the layer of litter extending from just below the surface to three-fourths inch below the surface.

10-HOUR TIMELAG FUEL MOISTURE (10-h TL FM).--The moisture content of the 10-hour timelag roundwood fuels.

THERMOSCREEN.--See Instrument Shelter.

TIMELAG (TL).--The time necessary for a fuel particle to lose approximately 63 percent of the difference between its initial moisture content and its equilibrium moisture content.

UNNORMALIZED MAN-CAUSED RISK.--The sum of the partial risks computed for the risk sources active on a protection unit.

VOLATILES.--Readily vaporized organic materials which, when mixed with oxygen, are easily ignited.

WET-BULB TEMPERATURE.--The temperature of a properly ventilated wet-bulb thermometer.

WINDSPEED.--Wind, in miles per hour, measured at 20 feet above the ground or the average height of the vegetative cover, and averaged over *at least* a 10-minute period.

APPENDIX B

SELECTION OF FUEL MODELS

Ideally, a protection unit should be subdivided into fire-danger rating areas of relatively homogeneous climate, fuels, and topography. Fire-danger rating values would be calculated for each rating area; a weighted average of these numbers would then determine the readiness plan for the protection unit.

At the present time, however, the protection unit is usually the smallest geographical division recognized. The protection unit may be quite homogeneous and satisfy the criteria for a fire-danger rating area. Most units, however, do not. For the calculation of the fire-danger ratings needed to manage fire suppression activities on such units, the fire manager must select an area he considers representative of the fire problem on the unit. We will call this area the *base area*--not to be confused with a fire-danger rating area.

Several options may be considered in selecting the base area:

1. It might be where most fires occur.
2. Where fires are most often fought.
3. Where the potential cost of suppression plus loss of resource and improvement is greatest.

Regardless of the option chosen, a careful study of the protection unit's fire history is essential.

The next step is to select the fuel model that best represents the fuels in the base area. Twenty fuel models are available to choose from. However, it is unlikely that more than two or three will be appropriate for any one protection unit.

The following key and narrative descriptions should help in selecting the correct fuel model.

With the exception of Model F, the fuel models carried over from the 1972 NFDRS have retained their letter designations. The 1972 NFDRS Fuel Model F was seldom used, so for 1978, the F designator was assigned to the intermediate brush fuel model.

FUEL MODEL KEY

- I. Mosses, lichens, and low shrubs predominate ground fuels.
  - A. An overstory of conifers occupies more than one-third of the site .... MODEL Q
  - B. There is no overstory, or it occupies less than one-third of the site (tundra) .... MODEL S
- II. Marsh grasses and/or reeds predominate .... MODEL N
- III. Grasses and/or forbs predominate.
  - A. There is an open overstory of conifer and/or hardwood trees .... MODEL C
  - B. There is no overstory.
    - 1. Woody shrubs occupy more than one-third, but less than two-thirds of the site .... MODEL T
    - 2. Woody shrubs occupy less than one-third of the site.
      - a. The grasses and forbs are primarily annuals .... MODEL A
      - b. The grasses and forbs are primarily perennials .... MODEL L
- IV. Brush, shrubs, tree reproduction or dwarf tree species predominate.
  - A. Average height of woody plants is 6 ft or greater.
    - 1. Woody plants occupy two-thirds or more of the site.
      - a. One-fourth or more of the woody foliage is dead.
        - (1) Mixed California chaparral .... MODEL B
        - (2) Other types of brush .... MODEL F
      - b. Up to one-fourth of the woody foliage is dead .... MODEL Q
      - c. Little dead foliage .... MODEL O
    - 2. Woody plants occupy less than two-thirds of the site .... MODEL F
  - B. Average height of woody plants is less than 6 ft.
    - 1. Woody plants occupy two-thirds or more of the site.
      - a. Western United States .... MODEL F
      - b. Eastern United States .... MODEL O
    - 2. Woody plants occupy less than two-thirds but greater than one-third of the site.
      - a. Western United States .... MODEL T
      - b. Eastern United States .... MODEL D
    - 3. Woody plants occupy less than one-third of the site.
      - a. The grasses and forbs are primarily annuals .... MODEL A
      - b. The grasses and forbs are primarily perennial .... MODEL L
- V. Trees predominate.
  - A. Deciduous broadleaf species predominate.

1. The area has been thinned or partially cut, leaving slash as the major fuel component.......... MODEL K

2. The area has not been thinned or partially cut.

a. The overstory is dormant; the leaves have fallen.......... MODEL E
b. The overstory is in full leaf.......... MODEL R

B. Conifer species predominate.

1. Lichens, mosses, and low shrubs dominate as understory fuels... MODEL Q
2. Grasses and forbs are the primary ground fuels.......... MODEL C
3. Woody shrubs and/or reproduction dominate as understory fuels.

a. The understory burns readily.

(1) Western United States.......... MODEL T
(2) Eastern United States.

(a) The understory is more than 6 ft tall.......... MODEL O
(b) The understory is less than 6 ft tall.......... MODEL D

b. The understory seldom burns.......... MODEL H

4. Duff and litter, branchwood, and tree boles are the primary ground fuels.

a. The overstory is overmature and decadent; there is a heavy accumulation of dead tree debris.......... MODEL G
b. The overstory is not decadent; there is only a nominal accumulation of debris.

(1) The needles are 2 inches or more in length (most pines).

(a) Eastern United States.......... MODEL P
(b) Western United States.......... MODEL U

(2) The needles are less than 2 inches long.......... MODEL H

VI. Slash is the predominant fuel.

A. The foliage is still attached; there has been little settling.

1. The loading is 25 tons/acre or greater.......... MODEL I
2. The loading is less than 25 tons/acre but more than 15 tons/acre.......... MODEL J
3. The loading is less than 15 tons/acre.......... MODEL K

B. Settling is evident; the foliage is falling off; grasses, forbs, and shrubs are invading the areas.

1. The loading is 25 tons/acre or greater.......... MODEL J
2. The loading is less than 25 tons/acre.......... MODEL K

FUEL MODEL A

This fuel model represents western grasslands vegetated by annual grasses and forbs. Brush or trees may be present but are very sparse, occupying less than one-third of the area. Examples of types where Fuel Model A should be used are cheatgrass and medusahead. Open pinyon-juniper, sagebrush-grass, and desert shrub associations may appropriately be assigned this fuel model if the woody plants meet the density criteria. The quantity and continuity of the ground fuels vary greatly with rainfall from year to year.

FUEL MODEL B

Mature, dense fields of brush 6 feet or more in height are represented by this fuel model. One-fourth or more of the aerial fuel in such stands is dead. Foliage burns readily. Model B fuels are potentially very dangerous, fostering intense, fast-spreading fires. This model is for California mixed chaparral generally 30 years or older. The F model is more appropriate for pure chamise stands. The B model may also be used for the New Jersey pine barrens.

FUEL MODEL C

Open pine stands typify Model C fuels. Perennial grasses and forbs are the primary ground fuel but there is enough needle litter and branchwood present to contribute significantly to the fuel loading. Some brush and shrubs may be present but they are of little consequence. Situations covered by Fuel Model C are open, longleaf, slash, ponderosa, Jeffrey, and sugar pine stands. Some pinyon-juniper stands may qualify.

FUEL MODEL D

This fuel model is specifically for the palmetto-gallberry understory-pine overstory association of the southeast coastal plains. It can also be used for the so-called "low pocosins" where Fuel Model O might be too severe. This model should only be used in the Southeast because of a high moisture of extinction.

FUEL MODEL E

Use this model after leaf fall for hardwood and mixed hardwood-conifer types where the hardwoods dominate. The fuel is primarily hardwood leaf litter. The oak-hickory types are best represented by Fuel Model E, but E is an acceptable choice for northern hardwoods and mixed forests of the Southeast. In high winds, the fire danger may be underrated because rolling and blowing leaves are not accounted for. In the summer after the trees have leafed out, Fuel Model E should be replaced by Fuel Model R.

FUEL MODEL F

Fuel Model F is the only one of the 1972 NFDRS Fuel Models whose application has changed. Model F now represents mature closed chamise stands and oakbrush fields of Arizona, Utah, and Colorado. It also applies to young, closed stands and mature, open stands of California mixed chaparral. Open stands of pinyon-juniper are represented; however, fire activity will be overrated at low windspeeds and where there is sparse ground fuels.

FUEL MODEL G

Fuel Model G is used for dense conifer stands where there is a heavy accumulation of litter and downed woody material. Such stands are typically overmature and may also be suffering insect, disease, wind, or ice damage--natural events that create a very heavy buildup of dead material on the forest floor. The duff and litter are deep and much of the woody material is more than 3 inches in diameter. The undergrowth is variable, but shrubs are usually restricted to openings. Types meant to be represented by Fuel Model G are hemlock-Sitka spruce, Coast Douglas-fir, and windthrown or bug-killed stands of lodgepole pine and spruce.

FUEL MODEL H

The short-needled conifers (white pines, spruces, larches, and firs) are represented by Fuel Model H. In contrast to Model G fuels, Fuel Model H describes a healthy stand with sparse undergrowth and a thin layer of ground fuels. Fires in H fuels are typically slow spreading and are dangerous only in scattered areas where the downed woody material is concentrated.

FUEL MODEL I

Fuel Model I was designed for clearcut conifer slash where the total loading of materials less than 6 inches in diameter exceeds 25 tons/acre. After settling and the fines (needles and twigs) fall from the branches, Fuel Model I will overrate the fire potential. For lighter loadings of clearcut conifer slash, use Fuel Model J, and for light thinnings and partial cuts where the slash is scattered under a residual overstory, use Fuel Model K.

FUEL MODEL J

This model complements Fuel Model I. It is for clearcuts and heavily thinned conifer stands where the total loading of materials less than 6 inches in diameter is less than 25 tons/acre. Again, as the slash ages, the fire potential will be overrated.

FUEL MODEL K

Slash fuels from light thinnings and partial cuts in conifer stands are represented by Fuel Model K. Typically the slash is scattered about under an open overstory. This model applies to hardwood slash and to southern pine clearcuts where the loading of all fuels is less than 15 tons/acre.

FUEL MODEL L

This fuel model is meant to represent western grasslands vegetated by perennial grasses. The principal species are coarser and the loadings heavier than those in Model A fuels. Otherwise the situations are very similar; shrubs and trees occupy less than one-third of the area. The quantity of fuel in these areas is more stable from year to year. In sagebrush areas Fuel Model T may be more appropriate.

FUEL MODEL N

This fuel model was constructed specifically for the sawgrass prairies of south Florida. It may be useful in other marsh situations where the fuel is coarse and reedlike. This model assumes that one-third of the aerial portion of the plants is dead. Fast-spreading, intense fires can occur even over standing water.

FUEL MODEL O

The O fuel model applies to dense, brushlike fuels of the Southeast. O fuels, except for a deep litter layer, are almost entirely living in contrast to B fuels. The foliage burns readily except during the active growing season. The plants are typically over 6 feet tall and are often found under an open stand of pine. The high pocosins of the Virginia, North and South Carolina coasts are the ideal of Fuel Model O. If the plants do not meet the 6-foot criteria in those areas, Fuel Model D should be used.

FUEL MODEL P

Closed, thrifty stands of long-needled southern pines are characteristic of P fuels A 2- to 4-inch layer of lightly compacted needle litter is the primary fuel. Some small diameter branchwood is present but the density of the canopy precludes more than a scattering of shrubs and grass. Fuel Model P. has the high moisture of extinction characteristic of the Southeast. The corresponding model for other long-needled pines is U.

FUEL MODEL Q

Upland Alaskan black spruce is represented by Fuel Model Q. The stands are dense but have frequent openings filled with usually inflammable shrub species. The forest floor is a deep layer of moss and lichens, but there is some needle litter and small-diameter branchwood. The branches are persistent on the trees, and ground fires easily reach into the tree crowns. This fuel model may be useful for jack pine stands in the Lake States. Ground fires are typically slow spreading, but a dangerous crowning potential exists. Users should be alert to such events and note those levels of SC and BI when crowning occurs.

FUEL MODEL R

This fuel model represents the hardwood areas after the canopies leaf out in the spring. It is provided as the off-season substitute for E. It should be used during the summer in all hardwood and mixed conifer-hardwood stands where more than half of the overstory is deciduous.

FUEL MODEL S

Alaskan or alpine tundra on relatively well-drained sites is the S fuel. Grass and low shrubs are often present, but the principal fuel is a deep layer of lichens and moss. Fires in these fuels are not fast spreading or intense, but are difficult to extinguish.

FUEL MODEL T

The bothersome sagebrush-grass types of the Great Basin and the Intermountain West are characteristic of T fuels. The shrubs burn easily and are not dense enough to shade out grass and other herbaceous plants. The shrubs must occupy at least one-third of the site or the A or L fuel models should be used. Fuel Model T might be used for immature scrub oak and desert shrub associations in the West, and the scrub oak-wire grass type in the Southeast.

FUEL MODEL U

Closed stands of western long-needled pines are covered by this model. The ground fuels are primarily litter and small branchwood. Grass and shrubs are precluded by the dense canopy but occur in the occasional natural opening. Fuel Model U should be used for ponderosa, Jeffrey, sugar pine, and red pine stands of the Lake States. Fuel Model P is the corresponding model for southern pine plantations.

APPENDIX C

SELECTION OF SLOPE CLASS

In the 1972 NFDRS, three slope classes were used: 0-20 percent, 21-40 percent, and greater than 40 percent. This was not sufficient for mountainous areas where slopes to 100 percent are found.

The number of slope classes has been increased to five, with 90 percent the midpoint of the last class. The classes were selected so that the effect would double if the next higher slope class is used. In other words, slope class 5 will have 16 times (2^4) the effect as slope class 1.

The basic consideration for selecting the slope class is the topography in the base area where initial attack is commonly made. Once again, knowledge of the fire history of the protection unit is essential.

Slope class	*Slope (percent)*
1	0-25
2	26-40
3	41-55
4	56-75
5	greater than 75

APPENDIX D

LIGHTNING RISK

The assessment of lightning risk (LR) requires two inputs: the lightning risk scaling factor and the lightning activity level (LAL).

The *lightning risk scaling factor* is a multiplier that localizes the prediction of the basic lightning-caused fire occurrence model. It accounts for local storm and site characteristics not addressed by the prediction model. Guideline A contains the instructions for deriving the lightning risk scaling factor for a fire-danger rating area.

The *lightning activity level* (LAL) is a numerical rating from 1 to 6 keyed to the observed or forecasted state of thunderstorms and lightning in a rating area (guideline B).

The daily evaluation of LR is done in two steps:

1. Select the LAL that best represents the lightning and thunderstorm situation (forecasted) observed on each fire-danger rating area (forecast area) during the calendar day.
2. Calculate the LR. It will automatically be calculated if AFFIRMS is used. For those not using AFFIRMS, the directions and nomogram for figuring the LR manually are in *Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System* (Burgan and others 1977).

Guideline A: The Lightning Risk Scaling Factor.--The LR scaling factor is derived from local records of thunderstorm and lightning-caused fire occurrence records. It can be calculated with and without historical data on LAL's. Data on LAL's are only available since 1972. With data on LAL's the LR scaling factor is calculated as follows:

$$\text{LR scaling factor} = \frac{10 \times \Sigma \text{ FIRES}}{1.6 \times \Sigma \text{ LOI}}$$

where: Σ FIRES is the total number of lightning-caused fires occurring *within a 28-mile radius* of the station during the period of record.

Σ LOI is the total of the daily LOI's during the period of record. (This is available by years from FIRDAT (Furman and Helfman 1973; Furman and Brink 1976)).

EXAMPLE 1.--Forty-one lightning fires occurred within a 28-mile radius of the Hashknife Lookout in Arizona from 1974 through 1976. The yearly occurrence totals and the total of the LOI obtained from an FIRDAT run *using an initial LR scaling factor of 1.0* are summarized in the following tabulation.

Year	*Number of lightning fires*	*LOI total*
1974	12	214
1975	16	306
1976	13	272
	41	792

Calculating the LR scaling factor:

$$\text{LR scaling factor} = \frac{10 \times 41}{1.6 \times 792}$$

$$= 0.32$$

The second method of calculating the LR scaling factor is not as accurate as the first, but it will serve where there are no LAL data. Initially, records from adjacent forests, districts, or counties that have comparable fuel types and similar levels of lightning fire incidence should be consolidated. The resulting LR scaling factor can then be used for all of the units.

$$\text{LR scaling factor} = \frac{1}{0.75}\left[\frac{\Sigma\ \text{FIRES}}{\text{A} \times \Sigma\ \text{TSTM DAYS}}\right]$$

where: Σ FIRES is the total number of lightning-caused fires occurring on the area during the period of record.

Σ TSTM DAYS is the total number of days with reported thunderstorms during the period of record.

A is the size of the area in millions of acres.

0.75 is the number of lightning fires per million acres per thunderstorm day for the area used to develop the basic prediction model.

EXAMPLE 2.--The lightning fire and thunderstorm data for a National Forest in eastern Montana are summarized in the following tabulation. The forest area is 1.715 million acres.

Number of years	*Total number of lightning fires*	*Total number of thunderstorm days*
5	32	34

Calculating the LR scaling factor:

$$\text{LR scaling factor} = \frac{1}{0.75}\left[\frac{32}{1.715 \times 34}\right]$$

$$= 0.73$$

The LR scaling factor should be adjusted every 2 years to bring the model predictions in line with experience. If the LOI is properly derived, 0.1 fires per million acres should have occurred on the average per unit of LOI.

The adjustment to the LR scaling factor would be made as follows. Use at least 2 years of data for this computation:

$$\text{LR scaling factor (new)} = \text{LR scaling factor (old)} \times \left[\frac{10 \times \Sigma\ \text{FIRES}}{\text{A} \times \Sigma\ \text{LOI}}\right]$$

EXAMPLE 3.--The fire manager of the forest of example 2 wants to adjust the LR scaling factor for one planning zone. This particular zone is in the higher elevations of the forest where the fuel is primarily spruce and lodgepole pine. It covers 670,000 acres (0.67 million acres). The LOI's for the years 1976 and 1977 total 1,776; there were 191 fires. The old LR scaling factor as computed in example 2 is 0.73.

$$\text{LR scaling factor (new)} = 0.73 \times \left[\frac{10 \times 191}{0.67 \times 1{,}776}\right]$$

$$= 0.73 \times 1.61$$

$$= 1.17$$

Guideline B: The Lightning Activity Level.--The LAL forecasted for the current day is used to estimate the expected number of *new* fires in the rating area. The estimate of holdover or sleeper fires to be dealt with today is based on the LOI calculated for yesterday. The LAL used in yesterday's calculation must have been verified and, if necessary, the LOI corrected before being used. This is the responsibility of the fire weather observer.

Choosing the correct LAL is a difficult task. We have approached the problem from the perspective of the fire weather forecaster separately from that of the fire weather observer.

The Fire Weather Forecast

Forecast areas vary greatly in size but are seldom smaller than 2,500 square miles (1.6 million acres). Forecast areas will normally include all or portions of the fire-danger rating areas as delinated by the protection agency. Hence the predicted LAL for a forecast area may be used on several rating areas.

The predicted LAL should reflect the maximum level of activity expected in a forecast area. A prediction of average LAL would be no more valuable to the fire manager than a prediction of average temperature is to a citrus grower. For verification purposes a single observation of the predicted LAL should justify scoring the forecast as a "hit." If no observations of that LAL were made or if a higher LAL was reported, the forecast should be scored a "miss."

The Lightning Activity Level Guide for National Weather Service fire weather forecasters, table 7, contains information different from that provided to the protection organization's fire weather observers.

Table 7.--*Lightning activity level guide for fire weather forecasters*

LAL	Maximum radar echo height	Radar echos of indicated strength			
		Very light	Light	Moderate	Strong
	1,000's of ft MSL	*Minimum area coverage in percent*			
1	No echos	--	--	--	--
2	<28	10	5	--	--
3	26-32	20	10	5	--
4	30-36	20	10	5	--
5	>36	30	20	10	5
6[1]	--	--	--	--	--

---

[1] To be used for red-flag warnings for potentially extreme fire activity.

LAL's 1 through 5 correspond, roughly, to the five categories of thunderstorm density used for aviation route forecasts: none, isolated, few, scattered, and numerous. Lightning activity level 6 was added to describe the rare but very significant event known as the "lightning bust." In such situations the storms are characterized by high bases (as high as 15,000 feet above sea level), no precipitation, and a low frequency of cloud-to-ground lightning discharges (similar to LAL 3). A high percentage of strikes start fires.

LAL 6 may never occur in your forecast area. It is unlikely to occur in the eastern United States or west of the Cascades-Sierra crest. Thunderstorm activity corresponding to LAL 6 is most commonly observed in the Inland Empire, the Great Basin, and the Northern Rocky Mountains.

LAL's 4 and 5 are typically associated with fronts and squall lines. LAL's 2 and 3 represent the more common summer airmass thunderstorm events.

It is no longer necessary for the fire weather forecaster to predict if storms will be wet or dry. That factor was included in the model storms for LAL's 2 through 5. The forecaster should consider precipitation duration separately from that of the thunderstorm occurrence forecast. His prediction of precipitation duration should reflect what is expected *at the fire weather station* during the 24 hours from one basic observation time to the next. This is meant to be consistent with the policy of the National Weather Service regarding precipitation forecasts for the general public.

The Fire Weather Observation

The *Lightning activity level guide for observers* (table 8) describes clouds, storm, and lightning frequency criteria for classifying lightning events. Because the objective is to describe the lightning activity, lightning counts take precedence over the cloud-storm-rain narrative descriptions.

For instance, if the clouds should fit the LAL 3 descriptive criteria, but the lightning averages three cloud-to-ground discharges per minute, the LAL should be classified as a 4.

Also included in the *Lightning activity level guide for observers* is the relative frequency of occurrence of the various LAL's. For instance, LAL 6 is a rare event not likely to occur on more than 1 or 2 percent of the lightning days.

The observation of lightning (the LAL) should include what has happened within a 25 to 30 mile radius of the station (1.6 million acres).

The fire weather observer must obtain as much information as possible from all available sources to insure an accurate LAL observation. The fire weather forecaster has other sources of information on thunderstorm activity, and therefore, should be consulted if there is confusion over the selection of an LAL.

Table 8.--*Lightning activity level guide for fire weather observers*

LAL	Cloud and storm development	Individual storm cell--cloud to ground lightning discharges: Counts [1]cg/5 min	Counts cg/15 min	Average (cg/min)	Percent of thunderstorm days
1	No thunderstorms	--	--	--	--
2	Cumulus clouds are common but only a few reach the towering cumulus stage. A single thunderstorm must be confirmed in the rating area. The clouds mostly produce virga but light rain will occasionally reach the ground. Lightning is very infrequent.	1-5	1-8	<1	10
3	Cumulus clouds are common. Swelling and towering cumulus covers less than two-tenths of the sky. Thunderstorms are few, but two to three must occur within the observation area. Light to moderate rain will reach the ground, and lightning is infrequent.	6-10	9-15	1-2	35
4	Swelling cumulus and towering cumulus cover 2-3/10 of the sky. Thunderstorms are scattered but more than three must occur within the observation area. Moderate rain is commonly produced, and lightning is frequent.	11-15	16-25	2-3	35
5	Towering cumulus and thunderstorms are numerous. They cover more than three-tenths and occasionally obscure the sky. Rain is moderate to heavy, and lightning is frequent and intense.	>15	>25	>3	18
6[2]					<2

[1] Cloud-to-ground lightning discharges.
[2] Used for red-flag warnings of potential extreme fire activity.

APPENDIX E

MAN-CAUSED RISK

The assessment of man-caused risk (MCR) requires three inputs. The first input is a number *called the MCR scaling factor,* which adjusts the prediction of the basic man-caused fire occurrence model to fit local experience.

The second, the *risk source ratios*, represents the contributions of each of the eight standard statistical causes (*risk sources*) listed on any fire report (USDA Form 5100-29 or USDI Form D1-1201) to the man-caused fire problem. The MCR scaling factor and risk source ratios are both derived from an analysis of the succeeding 3 to 5 years of fire and fire weather data.

The third input, the *daily activity levels*, is the fire manager's estimate of the status of each of the *risk sources.*

The daily evaluation of MCR is done in three steps:

1. Select the *daily activity level* appropriate for each *risk source.*

2. Using nomogram E-1, determine the *partial risk* for each *risk source* from its *daily activity level* and *risk source ratio.* Sum up the partial risks to obtain the *unnormalized man-caused risk.*

3. Enter nomogram E-2 with the *unnormalized man-caused risk* and the protection unit's *MCR scaling factor* to obtain the MCR.

This procedure must be used to determine the MCR for *both* computer and manual calculations of NFDRS ratings. Working copies of E-1 and E-2 are provided in the back of this book.

Keyed to the information flow diagram in figure 3 are guidelines A through E, which tell how to determine the inputs and calculate the MCR.

Guideline A: The MCR Scaling Factor.--The most recent 5 years of fire and fire weather records are needed to evaluate the MCR scaling factor (3 years are sufficient in high man-caused fire areas). The analysis should be redone every 2 years so that current trends can be accounted for. The procedure for calculating the MCR scaling factor is:

1. Determine the total number of MC fires that occurred on protected land during the most recent 5 years (Σ FIRES).
2. Total the number of days in each of the five fire seasons and add together (Σ DAYS).
3. Determine the average of the daily values of IC for each of the five seasons. Calculate an overall average ($\overline{IC}$), weighting the yearly averages by the number of days in the respective season.
4. Determine the area of land protected in millions of acres and multiply by Σ DAYS. This value is million acre-days (A-DAYS).

MAN-CAUSED RISK

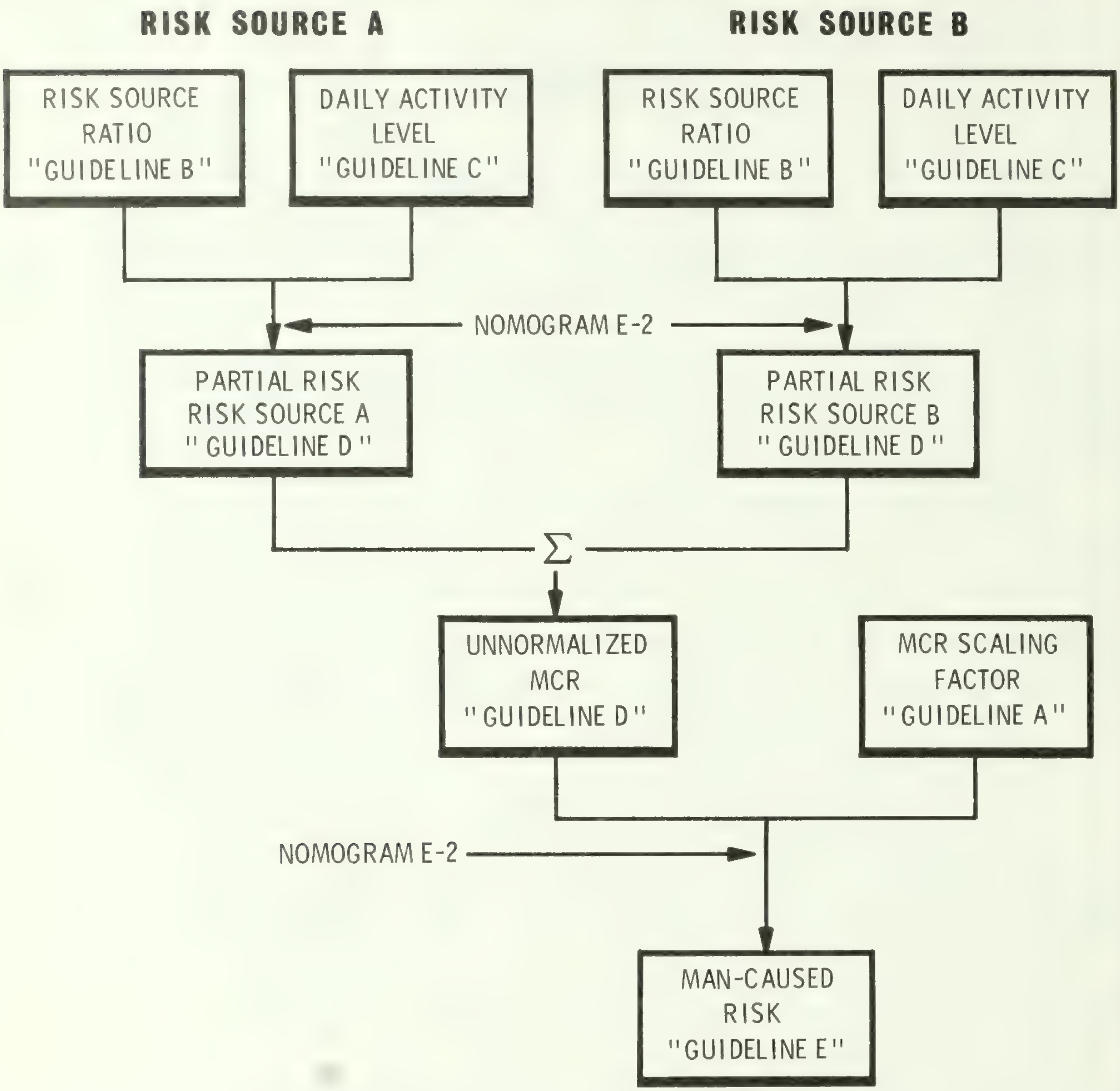

RISK SOURCE A
RISK SOURCE B
RISK SOURCE RATIO "GUIDELINE B"
DAILY ACTIVITY LEVEL "GUIDELINE C"
RISK SOURCE RATIO "GUIDELINE B"
DAILY ACTIVITY LEVEL "GUIDELINE C"
NOMOGRAM E-2
PARTIAL RISK RISK SOURCE A "GUIDELINE D"
PARTIAL RISK RISK SOURCE B "GUIDELINE D"
Σ
UNNORMALIZED MCR "GUIDELINE D"
MCR SCALING FACTOR "GUIDELINE A"
NOMOGRAM E-2
MAN-CAUSED RISK "GUIDELINE E"

Figure 3.--Computation flow chart for determining man-caused risk. Only two risk sources, A and B, are shown. In reality, three to five risk sources are used and the partial risks summed to produce the unnormalized man-caused risk.

5. Calculate the MCR scaling factor according to the following formula:

$$\text{MCR scaling factor} = \frac{10 \times \Sigma \text{ FIRES}}{\overline{\text{IC}} \times \text{A-DAYS}}$$

EXAMPLE.--The last five fire seasons in Pocossin County are summarized in the following tabulation.

a	*b*	*c*	*d*	*e*	*f*
Year	*No. of MC fires*	*Year's average IC*	*Fire season (days)*	*(c × d)*	$\overline{IC}$ *(Σe/Σd)*
1972	375	44.2	187	8,265	
1973	521	49.7	195	9,692	
1974	447	48.5	200	9,700	
1975	400	46.6	170	7,922	
1976	417	43.2	168	7,258	
	2,160		920	42,837	46.56 = 47

$\overline{\text{IC}}$ is the average of the yearly average IC's weighted by the number of days in the respective fire season. The weighting is done in columns e and f.

The third term in the equation is million acre-days (A-DAYS). It is the product of the protected area, in millions of acres, and the total number of days in the five fire seasons. The protected area in Pocossin County is 1.8 million acres.

$$\begin{aligned}\text{A-DAYS} &= \text{Area} \times \Sigma\text{d} \\ &= 1.8 \times 920 \\ &= 1{,}656\end{aligned}$$

Calculating the MCR scaling factor:

$$\text{MCR scaling factor} = \left[\frac{10 \times 2{,}160}{47 \times 1{,}656}\right]$$

$$= 0.28$$

If several protection units have about the same fuels, weather, and fire problem, a single MCR scaling factor can be developed from the combined data of the units. This is desirable because the larger number of data will produce a more stable MCR scaling factor.

Guideline B: Evaluation of the Risk Source Ratios.--The relative contributions to fire starts of the several risk sources active on a protection unit may change with day of the week. For that reason, a risk source ratio is calculated for each risk source for each of the 7 days of the week.

It is not necessary, or desirable, to follow all eight statistical causes. The risk sources selected for monitoring should, at a minimum, have accounted for 70 percent of the man-caused fires during the past 3 to 5 years. In most cases, fewer than five risk sources will satisfy the 70 percent rule.

EXAMPLE.--74 percent of the man-caused fires occurring in the North Carolina Count of Pocossin the past 5 years were attributable to incendiarism, debris burning, campfires, and machine use. The remainder of the causes are included in "all other."

Risk source	*No. of fires*	*Percent of fires*	
Incendiary	562	26	74%
Debris burning	475	22	
Campfires	194	9	
Equipment use	367	17	
All other	562	26	
Total	2,160	100	

By day of the week, the fires were distributed as follows:

	*Number of fires**							
Risk source	*Mon*	*Tues*	*Wed*	*Thur*	*Fri*	*Sat*	*Sun*	*Total*
Incendiary	9	26	60	72	80	80	72	399
Debris burning	29	37	43	60	143	264	100	677
Campfires	6	20	17	23	55	66	75	261
Equipment use	57	63	60	75	89	11	9	364
All other	49	63	80	52	57	89	69	459
5-YEAR TOTAL								2,160

*If less than five but more than zero fires occur, use 5.

The risk source ratio is calculated using this formula:

$$\text{Risk source ratio} = \frac{700 \times \text{No. of fires for day of week}}{\text{Total fires}}$$

For instance, the risk source ratio for debris burning for a Thursday would equal:

$$\frac{700 \times 60}{2{,}160} = 19$$

Using this formula, the array of risk source ratios by day of week for the five risk sources in the example looks like this:

	Risk source ratios						
Risk source	*Mon*	*Tues*	*Wed*	*Thurs*	*Fri*	*Sat*	*Sun*
Incendiary	3	8	19	23	26	26	23
Debris burning	9	12	14	19	46	86	32
Campfires	2	6	6	7	18	21	24
Equipment use	18	20	19	24	29	4	3
All others	16	20	26	17	18	29	22

Guideline C: Evaluation of the Daily Activity Level.--Unlike the risk source ratios and the MCR normalizing factor, which are semipermanent, objectively derived numbers, the daily activity levels must be evaluated each day. Because they are subjectively determined, the fire manager must monitor factors that might cause deviations in the status of the selected risk sources *from what is normal for that particular day of the week.*

Deviations from NORMAL are rare. NONE or EXTREME *might* occur only 10 percent of the time; LOW or HIGH, 20 percent of the time. The daily activity level guide is as follows:

DAL	*Relative value*	*Percentage of occurrence*	*Description*
NONE	0	5	Risk source totally inactive.
LOW	1	10	Risk source activity well below normal for the day of the week.
NORMAL	2	70	Activity typical for the day of the week.
HIGH	4	10	Risk source unusually active; about twice the typical level for the day.
EXTREME	8	5	Activity of the risk source unusually high. Appropriate only for risk sources that are highly variable such as incendiary.

Remember this very important principle: *The assessment is relative to what is normal for that day of a typical week during the fire season.* This is a significant refinement of the 1972 NFDRS procedures, where the reference was much less precisely defined.

Recreation-related activities are heavily influenced by the weather--current and forecasted. Other risk sources such as railroads are very persistent and should be carried as NORMAL, except under very unusual circumstances.

Risk source ratios will automatically account for the weekend peaks of recreational activity, but what about the 3-day weekend or a holiday in the middle of the week? On such occasions, HIGH or even EXTREME daily activity levels may be warranted for the risk source that covers recreation-related causes.

Consider seasonal influences also. Debris burning is primarily a fall and spring activity. During these periods, a HIGH or EXTREME rating can easily be justified. Some recreational pursuits, such as hunting, are also very seasonal.

Guideline D: Calculation of the Unnormalized Man-Caused Risk.--The partial risk contributed by each risk source is obtained from nomogram E-1. The inputs are the daily activity level and the risk source ratio of the particular risk source. The unnormalized man-caused risk is the *sum* of the partial risks contributed by each of the risk sources.

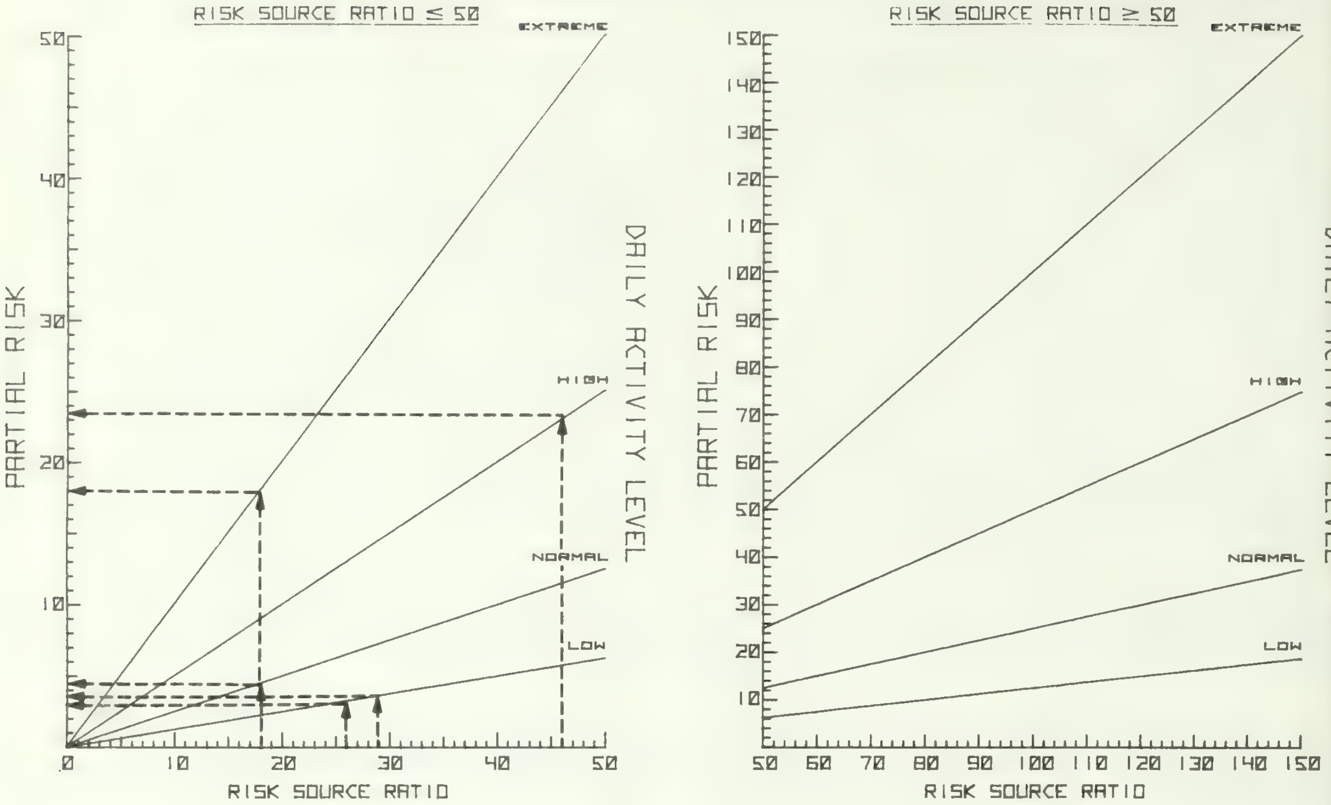
EXAMPLE: November 2 is Founder's Day, a holiday that falls on Friday. Nomogram E-1 is used to calculate the partial risks. The unnormalized man-caused risk is the sum of the partial risks--in this case, 53.

Risk source	*Risk source ratio*	*Daily activity level*	*Partial risk*
Incendiary	26	LOW	3
Debris burning	46	HIGH	23
Campfires	18	EXTREME	18
Machine use	29	LOW	4
All other	18	NORMAL*	5
UNNORMALIZED MAN-CAUSED RISK**			53

*The "all other" risk source is always assigned a daily activity level of NORMAL.
**The unnormalized MCR may total more than 100.

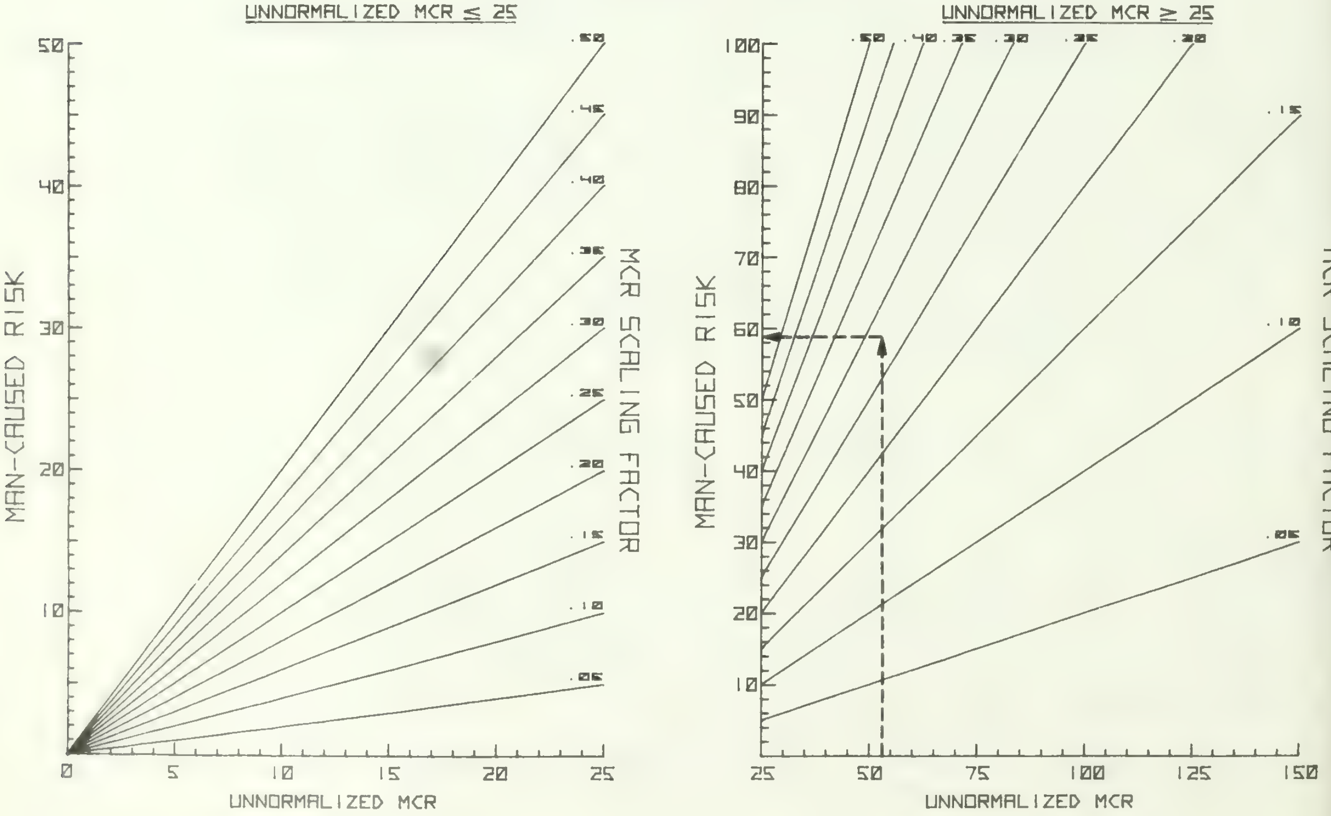
NOMOGRAM E-1

PARTIAL RISK



NOMOGRAM E-2

MAN-CAUSED RISK



Guideline E: Calculation of Man-Caused Risk.--The value of MCR entered into the computer or into column 18 of the 10-day fire danger and fire weather record, if you are calculating the NFDRS ratings manually, is determined with nomogram E-2. The unnormalized man-caused risk and the MCR scaling factor are the inputs.

EXAMPLE: Again consider Pocossin County; entering nomogram E-2 with an unnormalized man-caused risk of 53 and an MCR scaling factor of 0.28. The MCR is 58. MCR cannot exceed a value of 100

Figure 4 is a suggested form for computing man-caused risk that the user may find convenient to copy and reproduce.

MAN-CAUSED RISK COMPUTATION FORM

Unit____________________ Date__________

MCR scaling factor________________ Day of week________

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1.			
2.			
3.			
4.			
5.			

Total - Unnormalized MC RISK - - - - - - - - - - - - ________

MCR (E-2) - - - - - - - - - - - - - - - - - - - ________

Figure 4.--Form for computing man-caused risk.

Working copies of nomograms E-1 and E-2 are provided in the back of this book.

APPENDIX F

INTERPRETATION OF THE OCCURRENCE INDEXES

The Lightning Fire Occurrence Index (LOI) and the Man-Caused Fire Occurrence Index (MCOI) can be interpreted in units of fire density, fires per million acres. At a value of 100, either index projects an average of 10 fires per million acres. Or put another way, each unit of index indicates an expectation of 0.1 fire per million acres.

You must be careful not to take the projections too literally on any given day. The indexes are meant to indicate what will happen *on the average* under similar conditions.

OI's are easily translated from fires per million acres to fires per rating area. Simply multiply the respective OI's by the area of the rating area in millions of acres and divide by 10.

EXAMPLE: Pocossin County has a protected area of 1.8 million acres. When the MCOI equals 66 and the LOI equals 5, on the average, a total of 13 fires should be expected in the county.

OI	*Area of rating unit (10^6 ac)*	*Index value*	*Expected number of fires*
MCOI	1.8	66	12.0
LOI	1.8	5	1.0
			13.0

In the preceding example, the protection unit consists of only one rating area. That is, the fuels and topography are reasonably uniform and only one fire weather station is operated. What if this county extends over a portion of the Coastal Plains and the Piedmont? In this case the unit should be divided into two rating areas, hopefully each with its own fire weather station.

EXAMPLE: Pocossin County is divided into two rating areas, Plains and Piedmont. The areas are 1.5 and 0.3 million acres; the MCOI's are 66 and 53; and the LOI's are 5 and 0. About 10 fires are projected for the day.

Rating area	*OI*	*Area of rating unit (10^6 ac)*	*Index value*	*Expected number of fires*
Piedmont	MCOI	0.3	66	2.0
	LOI	0.3	5	.2
		Subtotal		2.2 fires
Plains	MCOI	1.5	53	8.0
	LOI	1.5	0	0
		Subtotal		8.0 fires
		Total		10.2 or 10 fires

APPENDIX G

INTERPRETATION OF THE BURNING INDEX

The summary publication of the 1972 NFDRS postulated that the effort required to contain a fire was proportional to the length of flames at the fire's head. New information indicates that difficulty of containment is proportional not to the flame length, but to the fireline intensity, the rate of heat release per unit length of fireline (Byram 1959). Following this latter hypothesis, the magnitude of the containment job actually increases more than twice as fast as the BI.

Flame length was related to fireline intensity by Byram (1959). Because the BI is based on flame length, the BI, fireline intensity, and flame length are interrelated.

Roussopoulos and Johnson (1975) compiled observations of Canadian, Australian, and American fire researchers relating fireline intensity to fire controllability and behavior. That information and the flame length and BI's corresponding to the critical fireline intensities are summarized in table 9.

It should be noted that the 1978 BI has been scaled to equal 78 when the predicted flame length is 7.8 feet. That flame length corresponds to a fireline intensity of 500 Btu/sec/ft. Above a fireline intensity of 500 Btu/sec/ft, it is unlikely that a fire can be controlled by conventional means. (Chemical retardants can possibly reduce the intensity of a fire below the 500 Btu/sec/ft level making direct attack feasible.)

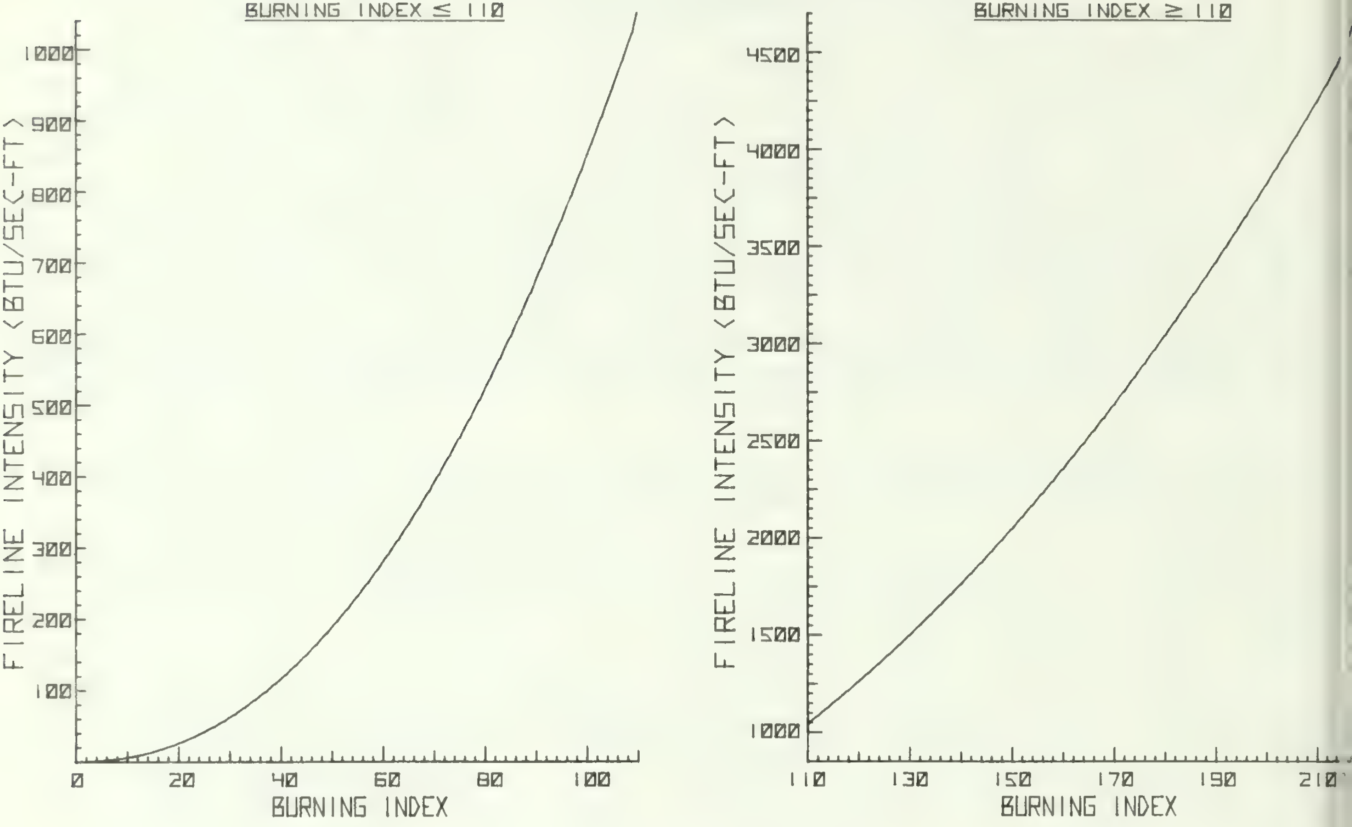
In nomogram G-1 the BI is plotted against fireline intensity. It can be used to derive *ideal* fireline intensity values from intermediate values of the BI.

Table 9.--*Fire behavior, controllability, and fireline intensity*

Burning index	Fireline intensity	Flame length	Narrative
	Btu/s/ft	*Ft*	
0-28	0-50	2.8	Most prescribed burns are conducted in this range
38	100	3.8	Generally represents the limit of control for manual attack methods.
78	500	7.8	The prospects for direct control by any means are poor above this intensity.
92	700	9.2	The heat load on people within 30 feet of the fire is dangerous.
108	1,000	10.8	Above this intensity, spotting, fire whirls, and crowning should be expected.

NOMOGRAM G-1

FIRELINE INTENSITY V/S BURNING INDEX



APPENDIX H

USING THE LIVE FUEL MOISTURE PREDICTION MODELS

Whether you are using AFFIRMS or calculating the fire-danger ratings manually, several procedures are common to both methods. The specifics for using AFFIRMS will be covered in a supplement to the AFFIRMS users' manual (Helfman and others 1975). Manual calculations will be covered in *Manually Calculating Fire-Danger Ratings--1978 National Fire-Danger Rating System* (Burgan and others 1977).

Two tasks must be completed prior to using the 1978 NFDRS:

1. Herbaceous fuels in each fire-danger rating area must be designated as annuals or perennials.

2. A climate class must be specified for each rating area.

During the fire season, the fire manager must monitor the condition of live fuels and signal the live fuel moisture prediction model when certain events occur. Those key events are: (1) greenup, whether it is the initial flush of growth in the spring or whether it occurs in midseason because of unusually high precipitation or some other cause; and (2) curing due to physiological processes or as a result of freezing.

Guideline A: Selecting the Annual or Perennial Designation for Herbaceous Fuels.--The live fuel moisture model predicts faster drying and curing rates for annual species than for perennials.

If more than half the herbaceous plants in a rating area are annuals, designate them as annuals. Otherwise, they are perennials. Seldom will the annual class be appropriate in mountainous areas or east of the 100th Meridian.

Fuel Model A *must* be given an annual designation and Fuel Model L *must* be given a perennial designation.

Guideline B: Selecting a Climate Class.--The four NFDRS climate classes correspond to the humidity provinces of Thornthwaite's first climate classification system (Thornthwaite 1931). In adapting his system, we grouped the arid provinces with the semiarid provinces in climate class 1 because the true desert is of little real concern to fire management. Also, in terms of fire behavior, the subhumid province with adequate year-long precipitation groups better with the humid province than with the dry, subhumid province. Table 10 summarizes the characteristics of the climate classes and figure 5 shows their general distributions.

Table 10.--*Climate class selection guide.*

NFDRS climate class	Thornthwaite[1] humidity province	Characteristic vegetation	Regions
1	Arid	Desert (sparse grass and scattered shrubs)	Sonoran deserts of west Texas, New Mexico, southwest Arizona, southern Nevada, and western Utah; and the Mojave Desert of California.
	Semiarid	Steppe (short grass and shrubs)	The short grass prairies of the Great Plains; the sagebrush steppes and pinyon/juniper woodlands of Wyoming, Montana, Idaho, Colorado, Utah, Arizona, Washington, and Oregon; and the grass steppes of the central valley of California.
2	Subhumid (rainfall deficient in summer	Savanna (grasslands, dense brush and open conifer forests)	The Alaskan interior; the chaparral of Colorado, Arizona, New Mexico, the Sierra Nevada foothills, and southern California; oak woodland of California; ponderosa pine woodlands of the West; and mountain valleys (or parks) of the Northern and Central Rockies.
3	Subhumid (rainfall adequate in all seasons)	Savanna (grasslands and open hardwood forests)	Blue stem prairies and blue stem-oak-hickory savanna of Iowa, Missouri, and Illinois.
	Humid	Forests	Almost the entire eastern United States; and those higher elevations in the West that support dense forests.
4	Wet	Rain forest (redwoods, and spruce-cedar-hemlock)	Coast of northern California, Oregon, Washington, and southeast Alaska.

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[1] Thornthwaite 1931.

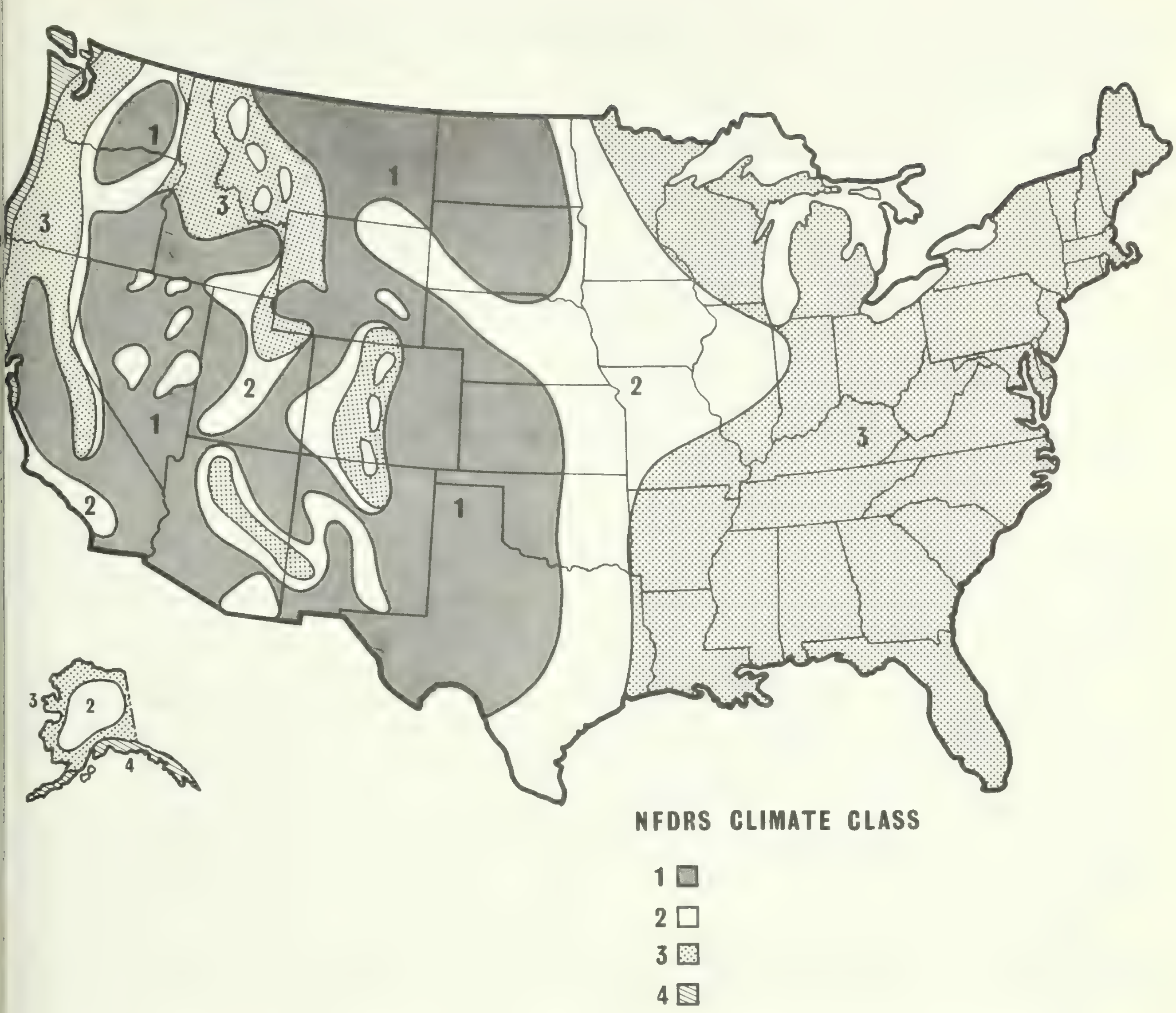

Figure 5.--Map of the United States showing the general locations of the NFDRS climate classes. The descriptions of the NFDRS climate classes, the geographical areas where they should be used, and the characteristic vegetation of those areas are tabulated in table 10.

The rules for selecting a climate class are flexible. The objective is to select the climate class that produces the best assessment of live fuel moisture conditions in the rating area. For instance, in the same geographical region a climate class for an area at high elevation will likely be different than the one used for rating areas at lower elevations.

There is nothing to prevent you from changing climate classes in the middle of the season. If the System is drying the live fuels too rapidly, go to the next lower climate class, namely, 2 instead of 3. Conversely, if the System is not drying the live fuels rapidly enough, use the next higher climate class, namely, 4 instead of 3.

However, you should be able to make a reasonable choice before hand by making FIRDAT runs (Furman and Helfman 1973; Furman and Brink 1976) for key stations using several climate classes. Choose the one that produces the best fit between the predicted and the observed live fuel conditions.

Selecting the climate class requires judgment and knowledge of the areas being rated. Climate class enables the user to *tune* the NFDRS to his area.

Guideline C: Greenup.--In all but the tropical areas of the United States, greenup will occur rather suddenly in the spring with warming temperatures. Greenup is signaled by the emergence of new growth on shrubs and trees, and the sprouting of herbaceous plants. In desert areas, or where the herbaceous ground cover consists primarily of annuals, rainy periods often cause a flush of new growth in the middle of the growing season.

In the interactive, time share computer program AFFIRMS, greenup is phased in over a period dependent on the climate class of the station. The time allowed for complete greenup is 7, 14, 21, and 28 days for climate classes 1, 2, 3, and 4, respectively. Hence, AFFIRMs users should declare greenup at the earliest appropriate time.

For those calculating the ratings manually, the greenup phasing feature is not available. In such cases, the user must not declare greenup until new growth is widespread. Otherwise, a premature reduction in the fire-danger ratings may result.

Guideline D: Curing.--Curing of the herbaceous fuels can come about in two ways: physiologically or due to freezing. Annuals normally complete their life cycle--sprout, flower, and produce seed--well within the normal growing season.

Perennial species usually cure very late in the season when temperatures drop below what is necessary for growth. Also, several days of below freezing temperatures or a single hard freeze may bring about a sudden end to growth in perennial herbs and forbs and in woody shrubs.

It is very important that you indicate when a cured condition exists. If the model has not already cured the herbaceous plants out, your signal will cause it to do so. As when declaring greenup, be careful to indicate curing only when the process is nearly complete. The fire-danger ratings may show a sudden increase when curing is declared, particularly for those fuel models having a high proportion of live woody material.

Guideline E: Coding Greenup and Curing.--In both the manual and computerized systems, spring or midseason greenups are indicated by a G for the herbaceous vegetation condition on *the day it occurs*. Curing without a freeze will be indicated by a C and curing by a freeze an F. In AFFIRMS the change in herbaceous vegetation condition is entered into the station catalog. In the manual system it will be entered in column 9 of the 10-day Fire Danger and Fire Weather Record.

APPENDIX I

THE 10-HOUR TIMELAG FUEL MOISTURE

The 10-h TL FM can be estimated using either of two methods:

1. From the weighing of the standard array of 1/2-inch ponderosa pine fuel sticks.

2. From mathematical models that require temperature, relative humidity, precipitation, and insolation data.

If the user chooses not to weigh fuel sticks and is subscribing to the AFFIRMS program, the 10-h TL FM will be automatically computed by the predictive model developed by NFDRS research. If the user is computing fire danger manually, the procedure for estimating the 10-h TL FM is covered by Burgan (Burgan and others 1977, appendix B).

The first option is preferred and recommended. Fuel sticks integrate the whole of the environment, including the effects of varying day length and cloudiness, better than any conceivable computational scheme.

In the 1972 NFDRS, the fuel stick moisture values were used directly as the 10-h TL FM. However, a number of workers (Nelson 1956; Morris 1959; Haines and Frost[3]) have shown that weathering significantly reduces the dry weight of fuel moisture sticks. If that weight loss is not taken into account, the reported moisture contents will be lower than actual; the result is an inflated fire-danger rating.

The nomogram I-1 is to be used for estimating the 10-h TL FM from the fuel stick weight. Nomogram I-1 is taken from the recent study by Haines and Frost.[3] A working copy of I-1 is provided in the back of this book.

To use the nomogram, locate the value corresponding to the observed fuel stick moisture content on the x-axis (horizontal). Trace upward parallel to the y-axis until you intercept the diagonal line corresponding to the age of the fuel sticks (interpolate when required). The 10-h TL FM is read from the y-axis directly to the left of the intersection point.

EXAMPLE.--If the observed fuel stick moisture is 11.5 grams and the sticks have been used for 2 months, what is the correct 10-h TL FM?

Answer.--14.5 percent.

Clean and balance your scales frequently. Inspect the fuel sticks daily for rodent chewing and checking, and replace if any damage is discovered. A replacement set of sticks should be set out a minimum of 1 week before being used to rate fire danger.

Fuel sticks should be supported on a wire rack 10 inches above a conifer or hardwood leaf litter, sawdust, or wood chip covered surface. They should be located so as to be in full sun from at least 0900 to 1500 local time.

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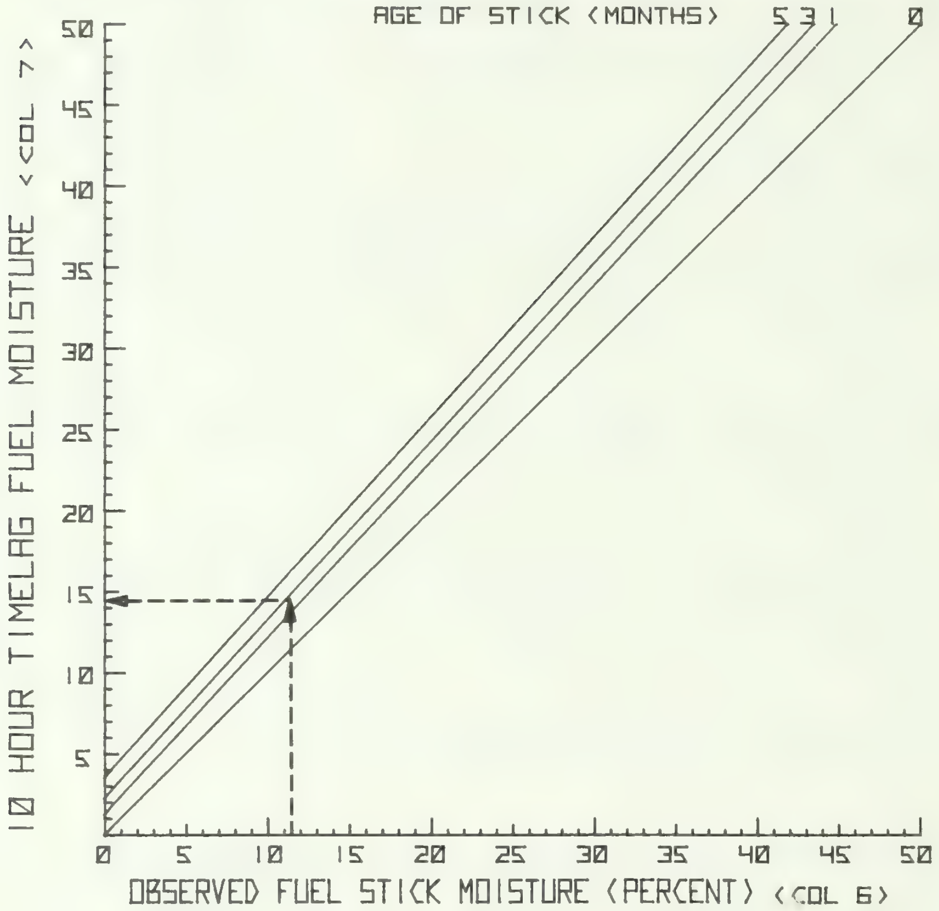
[3] Haines, Donald A., and John S. Frost. Weathering of 100-g (1/2-inch) fuel moisture sticks. USDA For. Serv. Res. Note, North Cent. For. Exp. Stn., St. Paul, Minn. (in preparation).

NOMOGRAM I-1

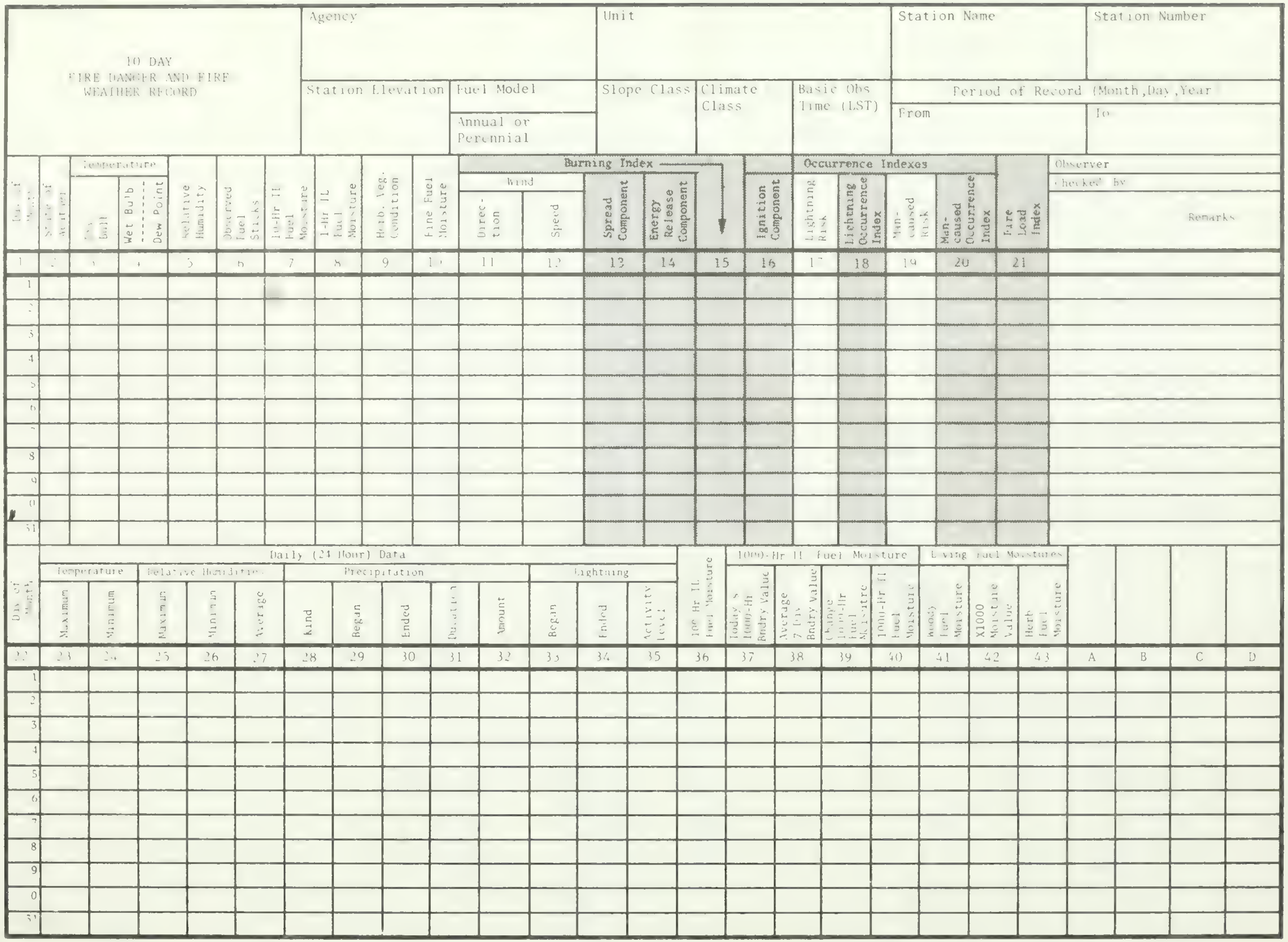
10 HOUR TIMELAG FUEL MOISTURE



APPENDIX J

THE 10-DAY FIRE DANGER AND FIRE WEATHER RECORD

This form (fig. 6) and the instructions for its use that follow have been proposed to the National Weather Service to replace the WS Form D-9a. The new form has been designed to serve both as a worksheet for manually calculating the fire-danger ratings manually and as a weather recording form.



10 DAY
FIRE DANGER AND FIRE
WEATHER RECORD

Agency
Unit
Station Name
Station Number
Station Elevation
Fuel Model
Annual or Perennial
Slope Class
Climate Class
Basic Obs Time (LST)
Period of Record (Month, Day, Year
From
To

		Temperature								Burning Index						Occurrence Indexes					Observer
										Wind											Checked by
Day of Month	State of Weather	Dry Bulb	Wet Bulb Dew Point	Relative Humidity	Observed Fuel Sticks	10-Hr TL Fuel Moisture	1-Hr TL Fuel Moisture	Herb. Veg. Condition	Fine Fuel Moisture	Direction	Speed	Spread Component	Energy Release Component		Ignition Component	Lightning Risk	Lightning Occurrence Index	Man-caused Risk	Man-caused Occurrence Index	Fire Load Index	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
0																					
31																					

	Daily (24 Hour) Data														1000-Hr TL Fuel Moisture				Living Fuel Moistures						
	Temperature		Relative Humidities			Precipitation					Lightning														
Day of Month	Maximum	Minimum	Maximum	Minimum	Average	Kind	Began	Ended	Duration	Amount	Began	Ended	Activity Level	100 Hr TL Fuel Moisture	Today's 1000-Hr Bndry Value	Average 7 Day Bndry Value	Change 1000-Hr Fuel Moisture	1000-Hr TL Fuel Moisture	Woody Fuel Moisture	X1000 Moisture Value	Herb Fuel Moisture				
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	A	B	C	D
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
0																									
31																									

Figure 6.--National Weather Service 10-Day fire danger and fire weather record. This form was designed for manual computation of the NFDRS. Its format follows the standardized sequence outlined by Burgan (Burgan and others 1977).

WS Form ____
Prec. by WCOM D-9a

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service

GENERAL INSTRUCTIONS

The WS Form ____ is designed to give uniformity to recordings of fire weather and fire-danger rating data. Objectives are:

1. To provide a means for recording weather and fuel data necessary for calculation of fire-danger rating values.

2. To facilitate computation of the fire-danger rating values.

3. To provide for the recording of selected climatological information.

The time of BASIC observation will be established by fire managers in consultation with the National Weather Service fire weather forecaster. Once the BASIC observation time is established, it should not be changed; for example, if the BASIC observation is established at 1300 local standard time (LST), then it should be taken at 1400 whenever daylight savings time (DST) is observed.

The WS Form ____ will be completed in duplicate; however, more or fewer copies may be required by your agency. Use fresh carbon paper and a hard pencil (2-3/4, 3, or 2H) with a sharp but rounded point. Please DO NOT use a ballpoint pen or typewriter. Entries must be neat and legible. On the 1st, 11th, and 21st days of each month, dispose of the forms for the preceding 10 days as your agency directs.

Questions concerning instructions, observations, or use of this form should be addressed to your fire weather forecaster.

RECORDING READINGS FROM INSTRUMENTS: ROUNDING OF ENTRIES--In reading thermometers and other instruments, values will seldom fall exactly on a graduation. If the value is halfway, or more than halfway, between two graduations, record the next highest value; if less than halfway, record the lower value. Example:

Thermometer reads 82.5°	Record 83
Rain measures 0.055 inch	Record 0.06
10 min average wind is 2.5 mi/h	Record 3
Fuel stick moisture content is 12.4%	Record 12
Average relative humidity is 42.5%	Record 43

STARTING THE WS FORM ____--Fill in all heading spaces to identify and locate your station; the name of your forest, district (BLM), county, etc., should be entered under "Unit." The "Station Number" will be provided by the fire weather forecaster. The "Fuel Model," "Slope Class," "Annual-Perennial," and "Climate Class" applicable to the rating area will be supplied by your local fire management officer. Using the 24-hour clock, enter the "Basic Observation Time" in local standard time (LST) EVEN WHEN DAYLIGHT SAVINGS TIME IS BEING OBSERVED.

This form is a 10-day record to cover the period(s) 1-10, 11-20, and 21-end of month. Make the appropriate "Period of Record" entry. NEVER ENTER DATA FROM MORE THAN ONE OF THESE PERIODS ON THE SAME SHEET. LEAVE BLANK THOSE LINES FOR DAYS WHEN OBSERVATIONS ARE NOT TAKEN.

At the beginning of the season, an initial value of 30 percent can be assumed for the 100-hour timelag fuel moisture (col. 36) and the 1,000-hour timelag fuel moisture (col. 40). Other starting values can be used if there is evidence that these values are inappropriate.

Column number — COLUMN INSTRUCTIONS

1 *Day of the Month.* In the first 10 days of the month (first decade) change the zero to 10. In the second decade, insert figures so days will read 11 to 20, and in the third decade, 21 to 30. Line 31 is used only in months having 31 days.

2 *State of Weather.* Record highest applicable code number describing the weather at BASIC observation time from the table below:

Code	*State of Weather*
0	Clear (less than 1/10 of sky cloud covered).
1	Scattered clouds (1/10 to 5/10 cloud covered).
2	Broken clouds (6/10 to 9/10 cloud covered).
3	Overcast (more than 9/10 of sky cloud covered).
4	Foggy.
5	Drizzling (precipitation of numerous fine droplets; in some areas referred to as "misting").
6	Raining.
7	Snowing or sleeting.
8	Showering (showers in sight or occurring at station).
9	Thunderstorm in progress (lightning seen or thunder heard). At lookout stations and others having unrestricted visibility, record thunderstorm in progress only when activity is not more than 30 miles away.

3 & 4 *Dry and Wet Bulb Temperatures.* Read thermometers to nearest whole degree. Use a minus sign to indicate temperatures below zero. If this form is being used to record forecasted weather information, the dew point can be recorded in col. 4 if needed.

5 *Relative Humidity.* Determine from National Weather Service psychrometric tables, series TA No. 454-0-1 (A, B, C, D, or E as appropriate for your elevation).

6 *Fuel Stick Weight.* Determine the weight of the 1/2-inch fuel moisture sticks to the nearest gram. If the sticks are snow or ice covered, or if it is raining at BASIC observation time, shake the snow, ice, or water from the sticks before weighing; enter 98 in col. 9.

7 *10-h Timelag Fuel Moisture.* Determine the fuel stick moisture content using the appropriate NFDR nomogram. If fuel sticks are not used, compute by the optional NFDR method.

8 *1-h Timelag Fuel Moisture.* Compute using the appropriate NFDR nomogram.

9 *Herbaceous Vegetation Condition.* This entry will be supplied by your local fire management officer in accordance with NFDR instructions. Code "G" for greenup; "C" for cured; and "F" if curing occurs due to a freeze.

10 *Fine Fuel Moisture.* Compute using the appropriate NFDR nomogram.

11 *Wind Direction.* Enter the direction FROM which wind is blowing. Make entry using following code: NE, 1; E, 2; SE, 3; SW, 5; W, 6; NW, 7; N, 8; Calm, 0.

12 *Windspeed.* Enter the 10-minute average speed to nearest whole mi/h.

olumn umber

COLUMN INSTRUCTIONS

3, 14, 5 & 16 *Spread Component, Energy Release Component, Burning Index, and Ignition Component.* Compute using the NFDR nomograms appropriate for your fuel model.

7 & 18 *Lightning Risk and Lightning Occurrence Index.* . Compute using the appropriate NFDR nomograms.

19 *Man-Caused Risk.* Compute in accordance with NFDR instructions.

0 & 21 *Man-Caused Occurrence Index and Fire Load Index.* Compute using the appropriate NFDR nomogram.

REMARKS.--Enter information such as "a second period of precipitation" or "thunderstorm event" and weather information that is not otherwise recorded, such as "rain changes to snow." Also, explain any data not clarified in a column entry, identifying data and column. For example: on the 9th at 1330, the wind shifted abruptly from SW at 15 mi/h to NW at 25 mi/h. Under remarks enter "col. 11--at 1330 wind shifted from SW 15 to NW 25." Note "fuels wet or snow (or ice) covered" when appropriate. Be sure entries begin on the line corresponding to the date of occurrence. Reasons for missing an observation should also be recorded. Make all entries as brief as possible.

DAILY (24-hour) DATA

Data in col. 23 through 26, 31, and 32 are for the period from BASIC observation time yesterday to BASIC observation time today. Entries in col. 29, 30, 33, 34, and 35 cover the period from 0001 to 2400 LST of the *date of occurrence.* (See example in col. 32 instructions.)

22 *Day of the Month.* See col. 1 instructions.

3 & 24 *Temperatures, Maximum and Minimum.** Record to the nearest whole degree. The maximum temperature (read today) cannot be lower than the dry-bulb temperature at observation time yesterday or today. The minimum temperature (read today) cannot be higher than the dry-bulb temperature at observation time yesterday or today.

5 & 26 *Humidity, Maximum and Minimum.*[1] If recording instruments are not available, estimate in accordance with the NFDR instructions.

27 *Average Relative Humidity.* Record to the nearest whole percent. Compute by adding the entries in col. 25 and 26 and dividing by two.

8 *Precipitation Kind.* Enter highest applicable code number as follows:

0	No precipitation	7	Snow or sleet
5	Drizzle	8	Showers
6	Rain	9	Hail

Note: If "zero" is entered in col. 28, leave col. 29, 30, 31, and 32 blank.

29 & 30 *Time Precipitation Began and Time Ended.** Use 24-hour clock, making entries to the nearest hour on the dateline of occurrence. Use "Remarks" space for indicating more than one period of precipitation. If beginnings and endings are unknown, estimate and note in "Remarks." Use the entry "cont" to denote precipitation continuing past midnight.

Column number	COLUMN INSTRUCTIONS

31 *Precipitation Duration.** This value should represent the total time that fuels were exposed to liquid water (rain) since BASIC observation time yesterday. If several periods of rainfall occurred, this value should be the cumulative total of the durations of all occurrences rounded to the next highest full hour. If it is raining at the time of BASIC observation, the duration of rainfall up to that time is recorded; the remainder of the storm will be accounted for the following day, *if, and only if the total duration of the storm for both days exceeds 1 hour.* Rains lasting less than one-half hour *and* producing only a trace amount should be disregarded. If more than a trace is received, a minimum of 1 hour should be entered in col. 31. Treat hail and snow as rain.

32 *24-hour Precipitation Amount.** Always empty the gage after taking a measure
If no precipitation occurs, record a zero. If less than 0.005 inch occurs, record as a trace (T). 0.005 inch will be recorded as 0.01 inch. Melt snow and hail and measure the same as rain.

Example of recordings for a rainfall event:

	Rain begins	*Rain ends*	*Measured at BASIC time of 1300 LST*
July 2	8:30 a.m.	12:15 p.m.	0.15
July 2	3:00 p.m.	5:30 p.m.	
July 2	8:30 p.m.	cont.	
July 3	cont.	2:30 a.m.	0.45

Record these events as follows:

Date	Kind	Time began	Time ended	Duration	Amount	Remarks
2	6	08	12	4	0.15	Rain 15-18 and 21 cont.
3	6	cont.	03	9	0.45	

33 & 34 *Time Lightning Began and Time Ended.* Use 24-hour clock, making entries to the nearest hour on the dateline of occurrence. Record when lightning is first seen or thunder heard. At lookout stations and others having unrestricted visibility, consider only those thunderstorms occurring within 30 miles of the observation station.

35 *Lightning Activity Level.* Complete in accordance with NFDR instructions.

36 *100-h Timelag Fuel Moisture.* Assume 30 percent for an initial 100-h timelag fuel moisture value in the spring. The "yesterday's" 100-h timelag fuel moisture input is the 100-h timelag fuel moisture from the previous day entry (col. 36). Compute using the NFDR nomogram.

37 *Today's 1,000-h BNDRY Value.* Compute using the appropriate NFDR nomogram.

Column number	COLUMN INSTRUCTIONS
38	*Average 7-day 1,000-h BNDRY Value.* Compute by summing the current day's and the previous 6 days' 1,000-h BNDRY values and divide by 7.
39	*Change in 1,000-h Timelag Fuel Moisture.* Compute using the appropriate NFDR nomogram. Record the change as positive (+) or negative (-). The "prior 7-day 1,000-h timelag fuel moisture" is the last entry in col. 40.
40	*1,000-h Timelag Fuel Moisture.* Compute by adding the (+) or (-) change in 1,000-h timelag fuel moisture from col. 39 to the previous 1,000-h timelag fuel moisture value in col. 40.
41	*Woody Fuel Moisture.* Compute using the appropriate NFDR nomogram.
42 & 43	*X1000 Moisture Value and Herbaceous Fuel Moisture.* The X1000 moisture value assumes the 1,000-h timelag fuel moisture value at the time herbaceous greenup occurs (triggered by herbaceous vegetation condition (col. 9)). Compute the X1000 value from the NFDR nomogram using the previous 7-day X1000 moisture value. Herbaceous fuel moisture is computed for annual or perennial vegetation from an NFDR nomogram.
A - D	These columns may be used for supplemental data, predictions, and so on.

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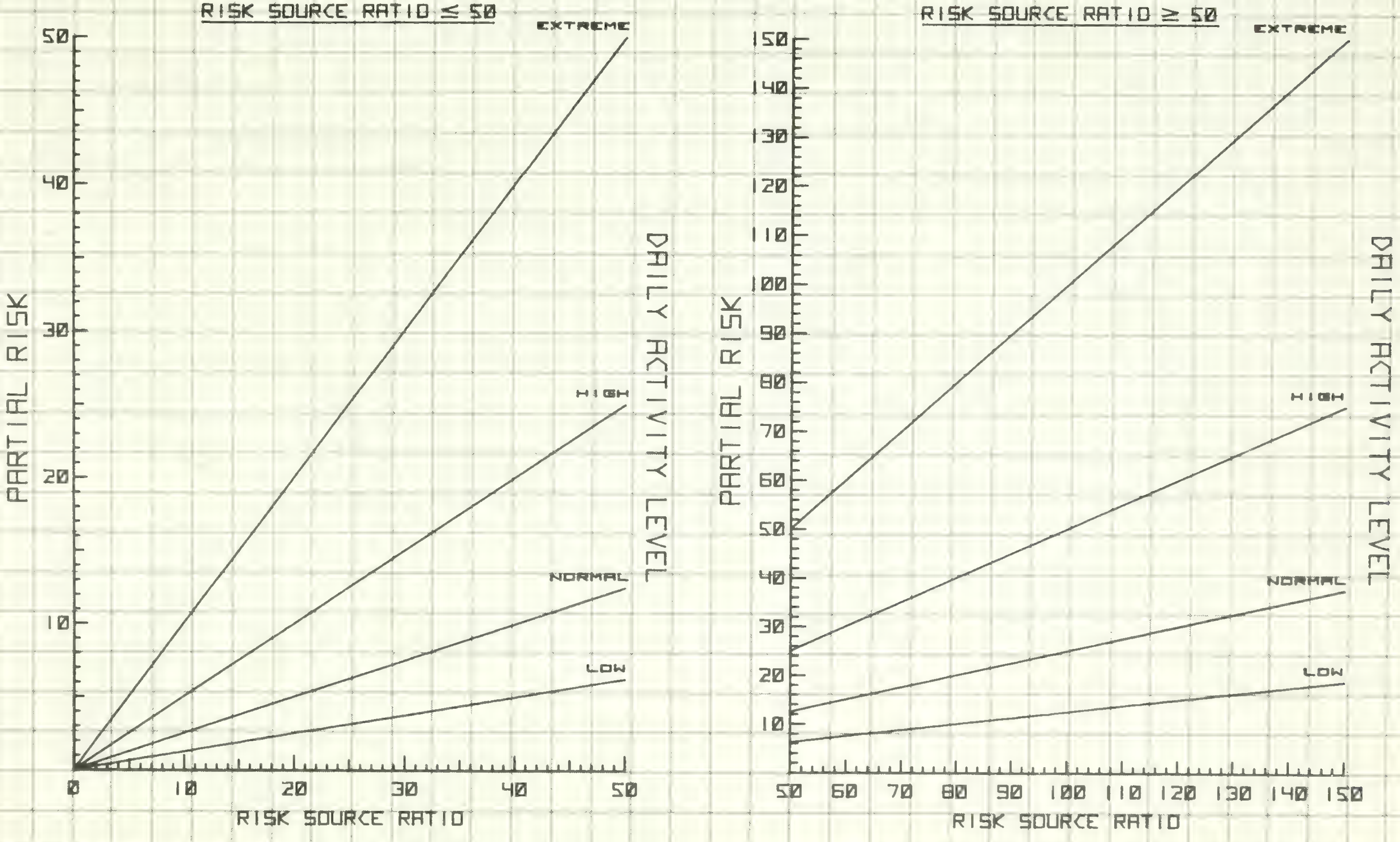
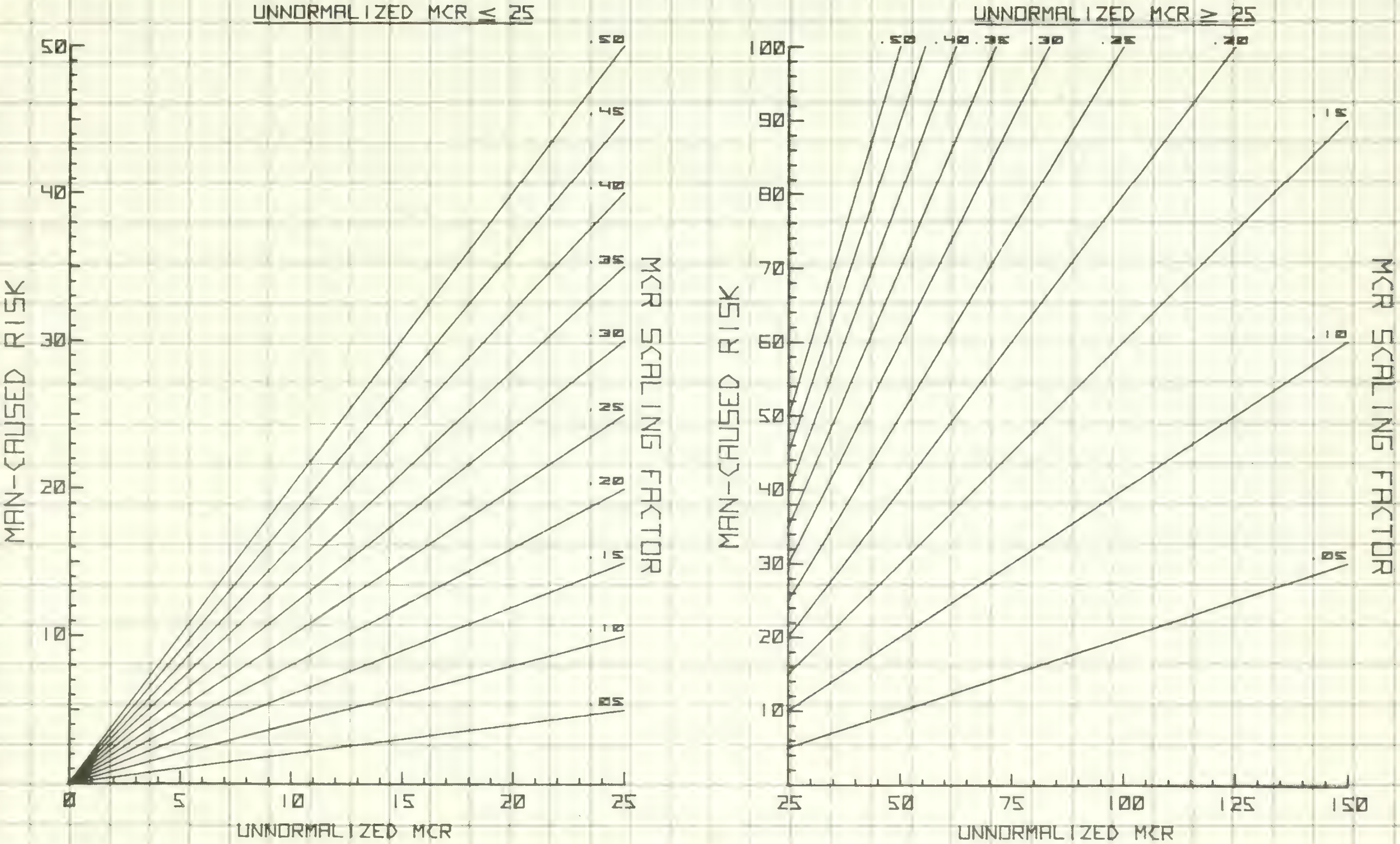
*If observations for a day are missed, estimate them using any available information. Explain under "Remarks."

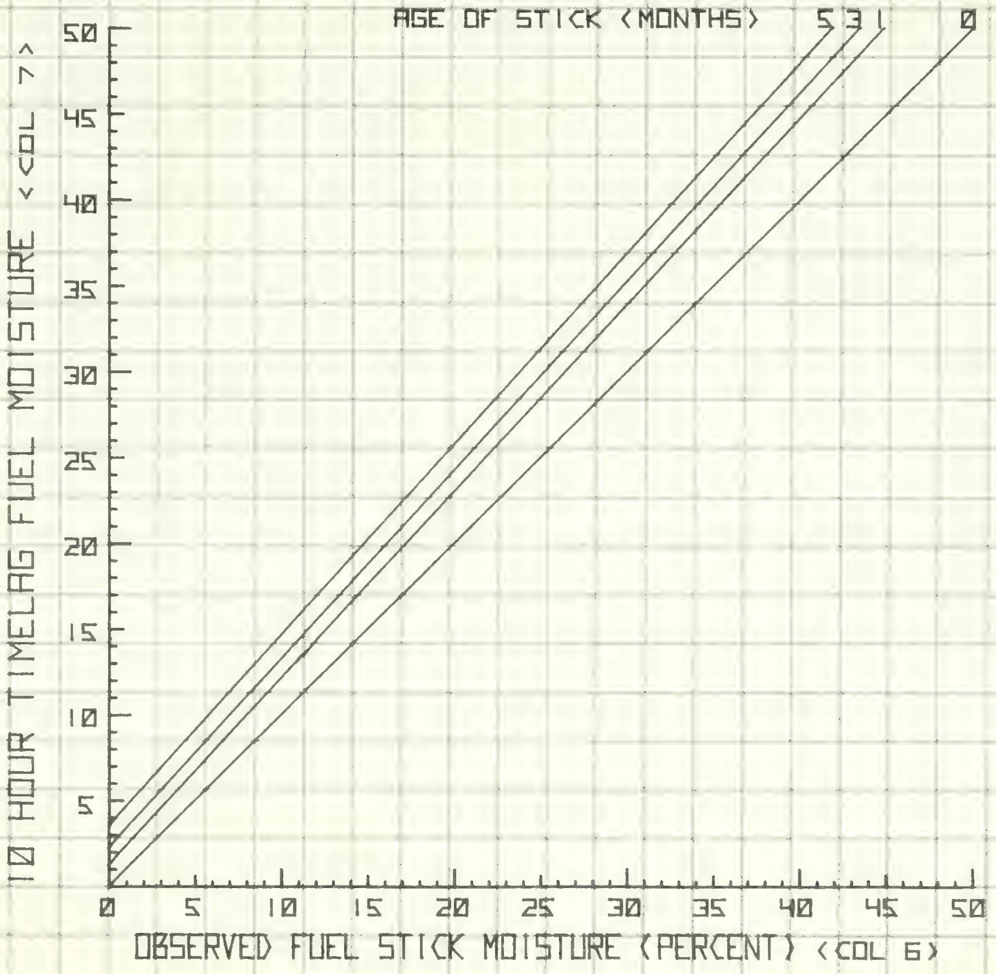
PARTIAL RISK



MAN-CAUSED RISK



10 HOUR TIMELAG FUEL MOISTURE



Deeming, John E., Robert E. Burgan, and Jack D. Cohen.
1977. The National Fire-Danger Rating System--1978. USDA For. Serv. Gen. Tech. Rep. INT-39, 63 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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The results of this work are presented in two publications. This publication covers the general information on the NFDRS and its application; a second publication (Burgan and others 1977) contains the nomograms and directions for calculating fire-danger ratings manually.

KEYWORDS: fire-danger rating, danger rating meters, burning index, fuel moisture content, lightning, man-caused forest fires, fire weather.

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☆ U.S. GOVERNMENT PRINTING OFFICE 1977-[illegible]

ATIONAL
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SDA Forest Service
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NTERMOUNTAIN FOREST
RANGE EXPERIMENT
TATION
OREST SERVICE
S. DEPARTMENT OF
GRICULTURE

MANUALLY CALCULATING FIRE-DANGER RATINGS — 1978 NATIONAL FIRE-DANGER RATING SYSTEM

Robert E. Burgan
Jack D. Cohen
John E. Deeming

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ERRATA SHEET

USDA Forest Service General Technical Report INT-40

Manually Calculating Fire Danger Ratings - 1978 National Fire Danger Rating System
by Burgan, Cohen, and Deeming

-Page 13--In the table listing items that should be set to 0 (zero) when it is raining at basic observation time, line out "Lightning Occurrence Index----".

-Page 14--In the paragraph headed *Lightning Risk (Column 17)*, the first sentence should read:

--If the Lightning Activity Level (column 35) is 1, record the LR (column 17) as zero.

Delete the sentence that begins "Skip--."

-Page 14--In the paragraph headed *Lightning-Caused Fire Occurrence Index (Column 18)*, delete "If the LAL is 1, the LOI is zero;"

-Page 35--The Risk Source Ratio for Campfires for Monday should read "12" not "6".

USDA Forest Service
General Technical Report INT-40
October 1977

MANUALLY CALCULATING FIRE-DANGER RATING — 1978 NATIONAL FIRE-DANGER RATING SYSTEM

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RESEARCH SUMMARY

This publication contains instructions for manually calculating the indexes and components of the 1978 National Fire-Danger Rating System (NFDRS). The procedures are explained with worked examples. Working sets of nomograms for the 20 NFDRS fuel models are not included. However, an order form for obtaining the needed nomograms is provided.

USDA Forest Service General Technical Report INT-39, The National Fire-Danger Rating System--1978 by John E. Deeming, Robert E. Burgan, and Jack D. Cohen, a companion publication, covers the NFDRS background, applications, and general principles of the system.

CONTENTS

Page

ABBREVIATIONS iv

PREFACE iv

WHY NOMOGRAMS ARE USED 1

DIFFERENCES BETWEEN MANUAL AND COMPUTER SYSTEMS 2

TYPES OF NOMOGRAMS 3

OBTAINING A SET OF NOMOGRAMS FOR FIELD USE 4

USING THE NOMOGRAMS 5

SPECIAL INSTRUCTIONS 11

COMPUTATIONAL PROCEDURES: A WORKED EXAMPLE AND EXERCISE 15

PUBLICATIONS CITED 42

APPENDIX A. --ESTIMATING THE MAXIMUM AND MINIMUM RELATIVE HUMIDITIES 43

APPENDIX B. --ESTIMATING THE 10-HOUR TIMELAG FUEL MOISTURE 45

APPENDIX C. --PUNCHCARD FORMAT FOR USE WITH THE 10-DAY FIRE DANGER AND FIRE WEATHER RECORD 48

ABBREVIATIONS

BI	Burning index
ERC	Energy release component
FLI	Fire load index
IC	Ignition component
LAL	Lightning activity level
LOI	Lightning-caused fire occurrence index
LR	Lightning risk
MCOI	Man-caused fire occurrence index
MCR	Man-caused risk
NFDRS	National Fire-Danger Rating System
SC	Spread component
TL	Timelag
1-h TL FM	1-hour timelag fuel moisture content
10-h TL FM	10-hour timelag fuel moisture content
100-h TL FM	100-hour timelag fuel moisture content
1,000-h TL FM	1,000-hour timelag fuel moisture content

PREFACE

At the time of this writing, the 1972 version of the National Fire-Danger Rating System (Deeming and others 1972) is being used by all Federal and 35 State agencies charged with protecting forest and range land from wildfire. The 1972 System was implemented as a manual system utilizing tables for computing the indexes and components. An interactive, time-share computer program to do the computations (AFFIRMS) was developed during the period 1972 to 1974 and was made available for general use in early 1975 (Helfman and others 1975). In 1976, about one-third of the data processed through the NFDRS was done manually. Though AFFIRMS usage is expanding, there is a continuing need for a method to compute the ratings by hand. This publication covers the manual procedures for the 1978 update of the NFDRS (Deeming and others 1977).

The manual procedures of the 1978 NFDRS are more complex than those of the 1972 System. With the addition of the 1,000-hour timelag fuel class, separate occurrence indexes for man-caused and lightning-caused fires, and a more comprehensive ignition component, increased complexity was unavoidable. But there have been trade-offs. For instance, an office procedure for determining live fuel moisture contents has been substituted for the bothersome and usually unsatisfactory field transects.

These procedures have been thoroughly tested. If you conscientiously work through the examples and problem set, you will find that it will take only a little longer to compute the 1978 ratings than it took for the 1972 ratings.

WHY NOMOGRAMS ARE USED

The 1978 NFDR indexes and components are calculated from nomograms that offer many advantages over the tables used for the 1972 NFDR System:

- Closer agreement between ratings calculated by the manual and computer systems.

- No need to arbitrarily establish class boundaries as when constructing tables.

- Better understanding of how factors such as temperature, relative humidity, windspeed, and slope affect indexes and components.

DIFFERENCES BETWEEN MANUAL AND COMPUTER SYSTEMS

To keep manual calculations within reason, the manual system has been simplified over the computer system. Therefore, while index and component values calculated from the nomograms will be close to those produced by the computer, the results cannot be expected to match perfectly. The significant differences between the two systems are:

1. In the manual system, an assigned temperature is used for the computation of the 1-, 10-, 100-, and 1,000-h TL fuel moistures. The observed temperatures are used in the computer version.

2. The 24-hour average relative humidity is used to calculate the 24-hour average equilibrium moisture content (EMC) in the manual system. But in the computer system, two EMC values are calculated: one from the maximum temperature and and minimum relative humidity; the other from the minimum temperature and maximum relative humidity. These two EMC values are then weighted by the hours of daylight and darkness to obtain a final 24-hour average EMC value. As a result, the computer version will predict higher 100- and 1,000-h TL fuel moistures than the manual system when the days are shorter than the nights; and lower 100- and 1,000-h TL fuel moistures when the days are longer than the nights.

3. In the manual system, the 1-h TL fuel moisture and the herbaceous fuel moisture are combined into a single value called the *fine fuel moisture*. The fin fuel moisture is an equivalent moisture content that can be used for dead and living fine fuels. It produces the same spread and energy release component values as if a separate accounting were made of the live and dead fuel moistures. In the computer version, the 1-h TL and herbaceous fuel moistures are kept separate.

4. Whenever the maximum likely effect of any particular dead or live fuel component is small, it is excluded for simplification. For example, the G model contains live woody material, but the effect of this material on the energy release component is small. So it is not included in the ERC calculation. However, because the woody material does have a significant effect on the rate of spread, it is included in that calculation.

5. The manual system assumes an immediate greenup when the growing season starts. The computer version, on the other hand, allows a gradual greening over a time period dependent upon the climate class.

6. The 1,000-h TL fuel moisture is updated weekly in the manual system, while it is updated daily in the computer version. During rainy periods, the 1,000-h TL fuel moisture can change rapidly. In such cases, the manual system will tend to overrate fire danger until the 1,000-h TL fuel moisture is recalculated.

TYPES OF NOMOGRAMS

Manual calculations utilize three general types of nomograms:

Type 1.--Those that are needed daily for most, if not all, fuel models:
- --1-h Timelag Fuel Moisture
- --10-h Timelag Fuel Moisture (computed)[1]
- --10-h Timelag Fuel Moisture (measured)
- --100-h Timelag Fuel Moisture
- --BNDRY Value (for the 1,000-h timelag fuel moisture)
- --Lightning Risk
- --Lightning Occurrence Index
- --Partial Risk
- --Man-Caused Risk
- --Man-Caused Fire Occurrence Index
- --Fire Load Index

Type 2.--Those used every *seventh* day for most, if not all, fuel models:
- --Change in 1,000-h Timelag Fuel Moisture
- --Woody Fuel Moisture
- --Herbaceous Fuel Moisture (perennial or annual)

Type 3.--Those used daily that are fuel model specific:
- --Fine Fuel Moisture
- --Ignition Component
- --Spread Component
- --Energy Release Component
- --Burning Index

---

[1] These are used (1) to estimate the current 10-h TL FM when fuel moisture sticks are not used and (2) for predicting the 10-h TL FM.

OBTAINING A SET OF NOMOGRAMS FOR FIELD USE

The nomograms in this manual are for instructional purposes only. You must order a working set for the fuel model(s) you intend to use.

Order one set of type 1 and type 2 nomograms for each station, and one set of type 3 nomograms for each fuel model to be used. For example, assume you are ordering nomograms for use at two fire weather stations: Lone Pine and Rocky Knob. Fuel models L, H, and C are used at Lone Pine; while Rocky Knob uses fuel models L and R. Order two sets of type 1 and type 2 nomograms, two sets of type 3 nomograms for model L, and one set each of type 3 nomograms for models H, C, and R. Once again, types 1 and 2 nomograms are needed for all fuel models, while type 3 nomograms apply only to specific fuel models. *To obtain the nomogram sets, use the order form on page 51, which can be completed and pasted on a post card.* Fuel models are described in the general treatment of the 1978 NFDRS (Deeming and others 1977).

After you receive your nomograms, eliminate any type 1 or type 2 nomograms not required for the fuel model(s) you intend to use. Not all calculations are needed because not all fuel classes are found in every fuel model. Refer to table 1 to determine which, if any, of the nomograms can be discarded.

Those nomograms designated by an X in the column headed by the fuel model designator can be discarded. For example, the 100-h TL FM and the woody fuel moisture nomograms can be discarded when using fuel model A. (Fuel model A has no 100-h TL or live woody fuels.) Fuel models E, F, G, H, P, Q, R, S, and U are not shown in table 1 because they require all the type 1 and type 2 nomograms. Once you have collected the nomograms needed for your fuel model(s), place them in plastic document protectors in a looseleaf binder.

Table 1.--*Nomogram discards*

Nomograms	Fuel model											
	A	B	C	D	F	I	J	K	L	N	O	T
100-h TL fuel moisture	X		X	X					X	X		X
Woody fuel moisture	X					X	X	X	X			
Herb. fuel moisture		X			X	X	X	X		X	X	

USING THE NOMOGRAMS

Nomograms are a graphic method for solving the mathematical equations that are the basis of the NFDRS. There are three different forms of nomograms, depending on the number of variables or factors needed to solve a particular equation:

> *1-part nomograms.*--Solve equations with two input variables, such as A + B = C where A and B are known (inputs) and C is the desired answer.
>
> *2-part nomograms.*--Solve equations with three input variables, such as A × B ÷ C = D where A, B, and C are the inputs and D is the desired answer.
>
> *3- and 4-part nomograms.*--Solve equations with four or five input variables, such as A + B + C + D + E = F. These are combinations of 1- and 2-part nomograms. An intermediate result from one nomogram is carried forward and used in a second nomogram.

For example, a 2-part and a 1-part nomogram may be combined to produce a 3-part nomogram. The first two steps may solve an equation of the form A + B + C = X, where A, B, and C are inputs and X is an intermediate value. This intermediate value is carried forward to a second nomogram to solve an equation of the type X + D = E, where X and D are the known values and E is the final answer.

The nomograms will be introduced by reviewing procedures for reading each form of nomogram.

The 1-part nomogram (fig. 1) consists of the x-axis, the y-axis, and one or several curves or straight lines.

To use the nomogram:

1. Locate the value of the first variable, A, on the x-axis.
2. Draw an imaginary line vertically to point B on the curve corresponding to the value of the second variable.
3. Extend a line horizontally to the left from B to C on the y-axis.
4. The desired answer is found at C.

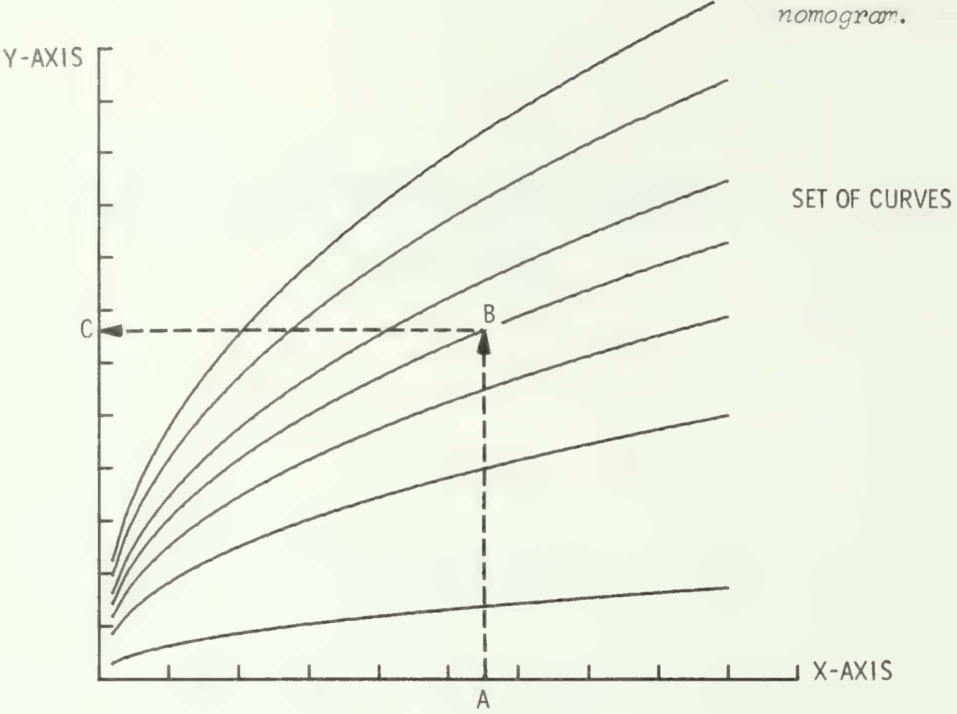


Figure 1.--1-part nomogram.

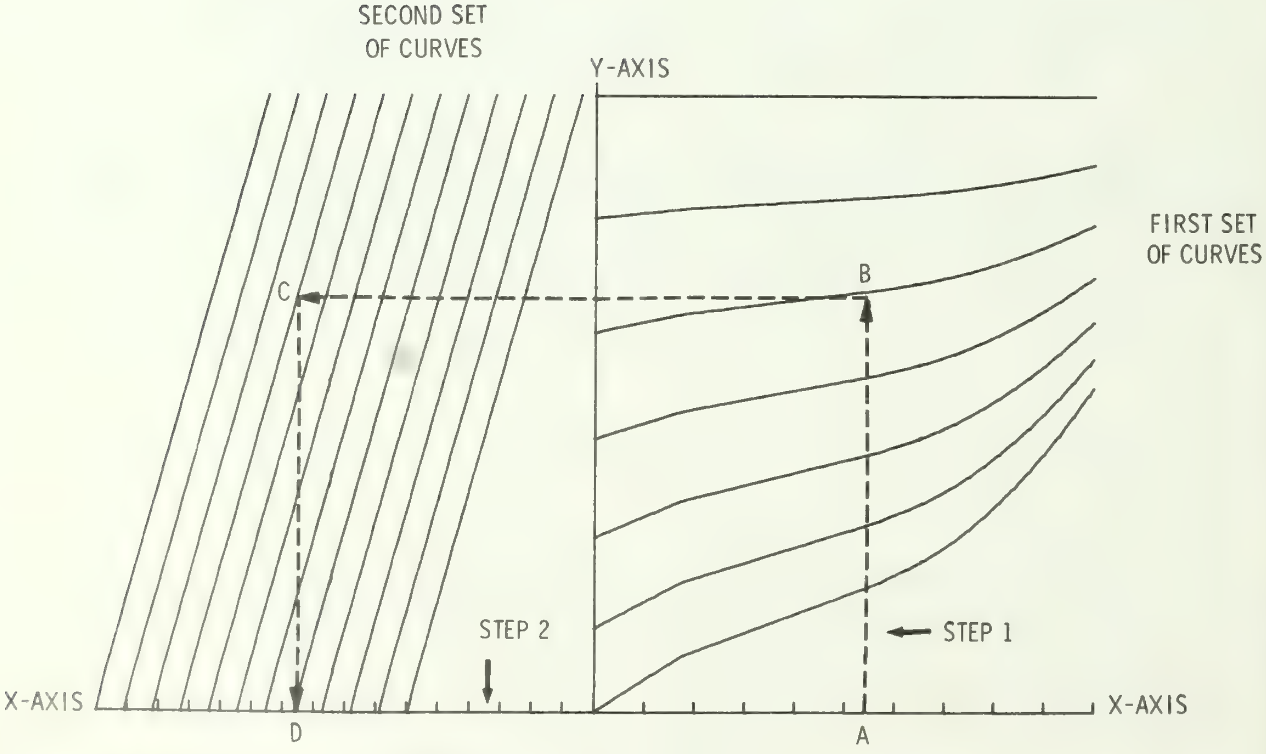


Figure 2.--2-part nomogram.

The 2-part nomogram (fig. 2) consists of the y-axis, the x-axis (extends left *and* right of its intersection with y-axis), and two families of curves or straight lines.

To use the nomogram:

1. Locate the value of the first variable, A, on the x-axis.
2. Draw an imaginary vertical line to point B on the curve corresponding to the value of the second variable.
3. Extend a line horizontally to the left from B to point C on the curve that represents the value of the third variable.
4. Extend a line vertically down from C to D, on the x-axis.
5. The desired answer is found at point D.

When constructing the nomograms, a standard procedure was set that would always result in reading an answer from either the y-axis or the left side of the x-axis. However, some computations require more than two steps. In such cases, an intermediate value must be brought forward for entry into a second nomogram.

The general form of the 3-part nomogram is shown in figure 3.

Steps 1 and 2 are carried out exactly as described for the 2-part nomogram, and step 3 is carried out exactly as described for the 1-part nomogram. But X, the value from step 2, must be brought forward for step 3 in the 1-part nomogram.

The 3-part nomogram does not always look exactly as shown. In some cases, the 1-part nomogram is first and the 2-part nomogram second.

In the construction of multiple-part nomograms, the intermediate value X can be entered on the x-axis or elsewhere in the body of the nomogram. In the sample 3-part nomogram, the intermediate value could have been entered at B, C, or D. You need only be aware that the intermediate value will not always be entered on the x-axis.

The sample 4-part nomogram (fig. 4) illustrates how this can be done. The 4-part nomogram is solved as though you were doing two 2-part nomograms in sequence. For illustrative purposes, the intermediate value (X) is one of the curves on the right side of the second nomogram. These procedures are extended to solve 5 or more part nomograms.

In the illustrations presented so far, the values of the variables have always been located exactly on a curve or line. When real data are used, they will seldom fall exactly on one of the curves of the nomogram. In such a situation, interpolation must be used. Example:

Given: 1-h TL FM = 7 percent
Dry bulb temperature = 80° F (27° C)
Spread component = 4

In this sample ignition component nomogram (fig. 5), start with the 1-h TL FM at 7 percent; go up to the point halfway between the 70° and 90° F temperature curves. Next, go left to a point one-third of the way between the 3 and 6 spread component curves. The ignition component is read directly below this point on the x-axis--20.

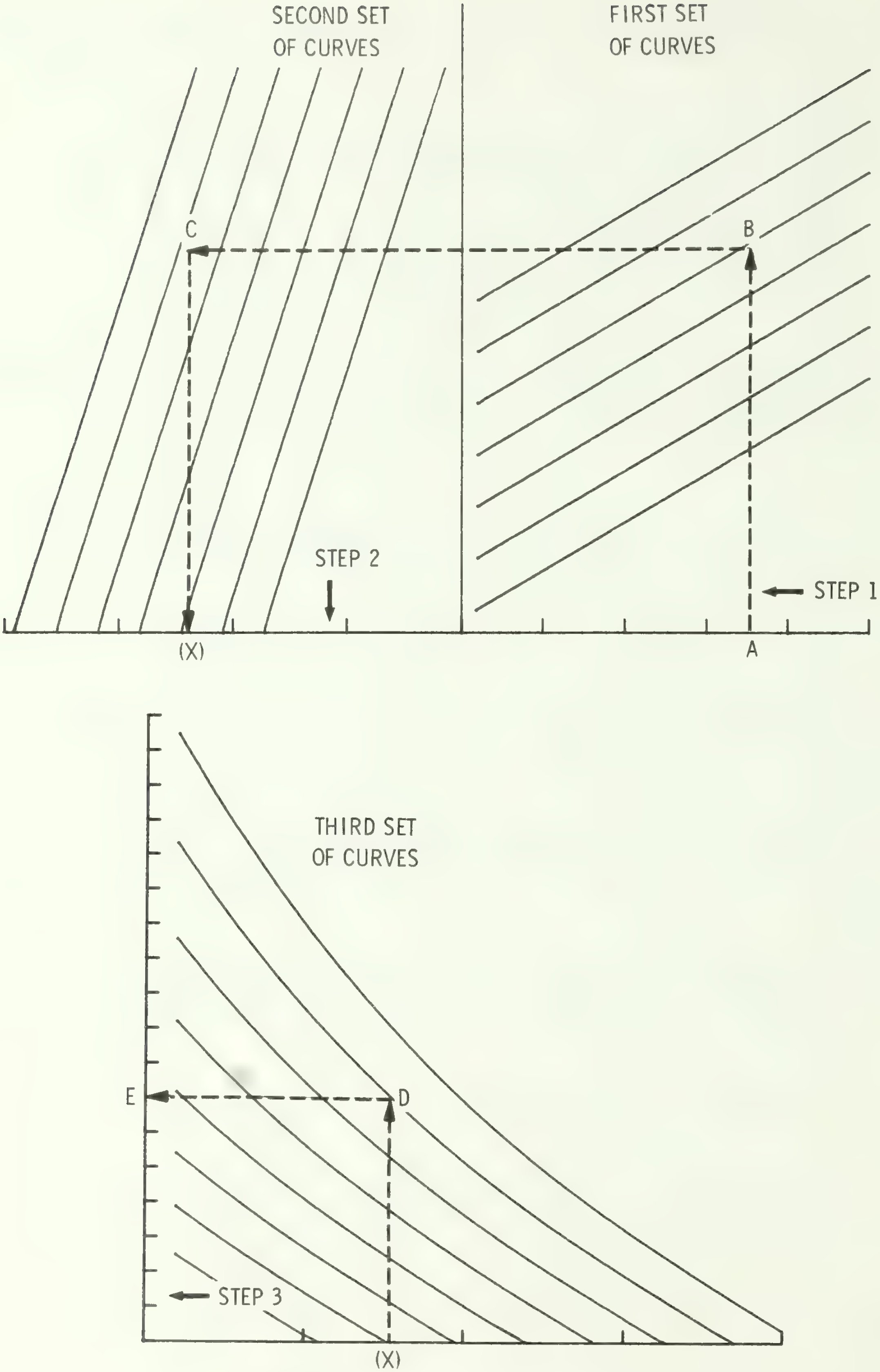


Figure 3.--3-part nomogram.

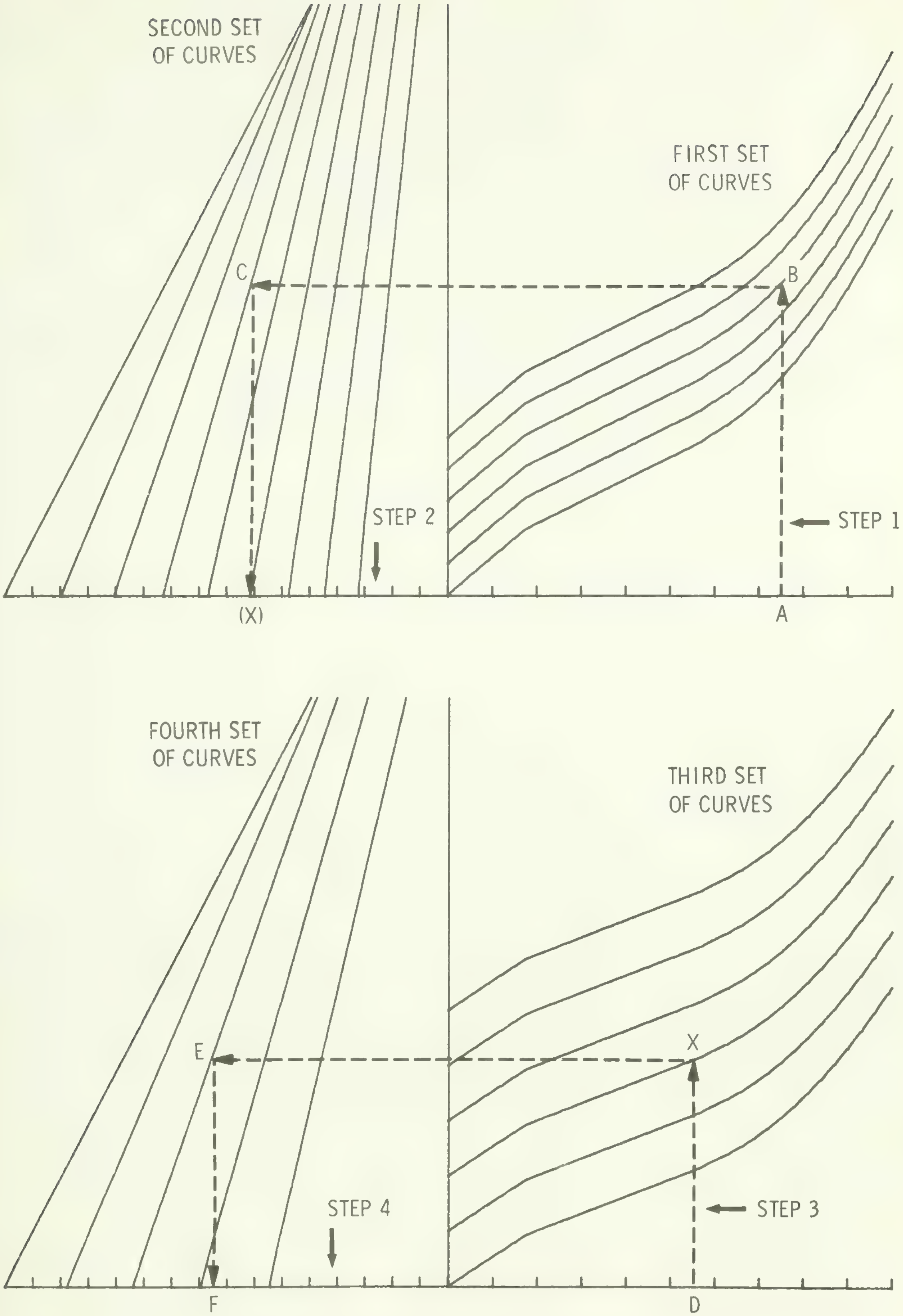


Figure 4.--4-part nomogram.

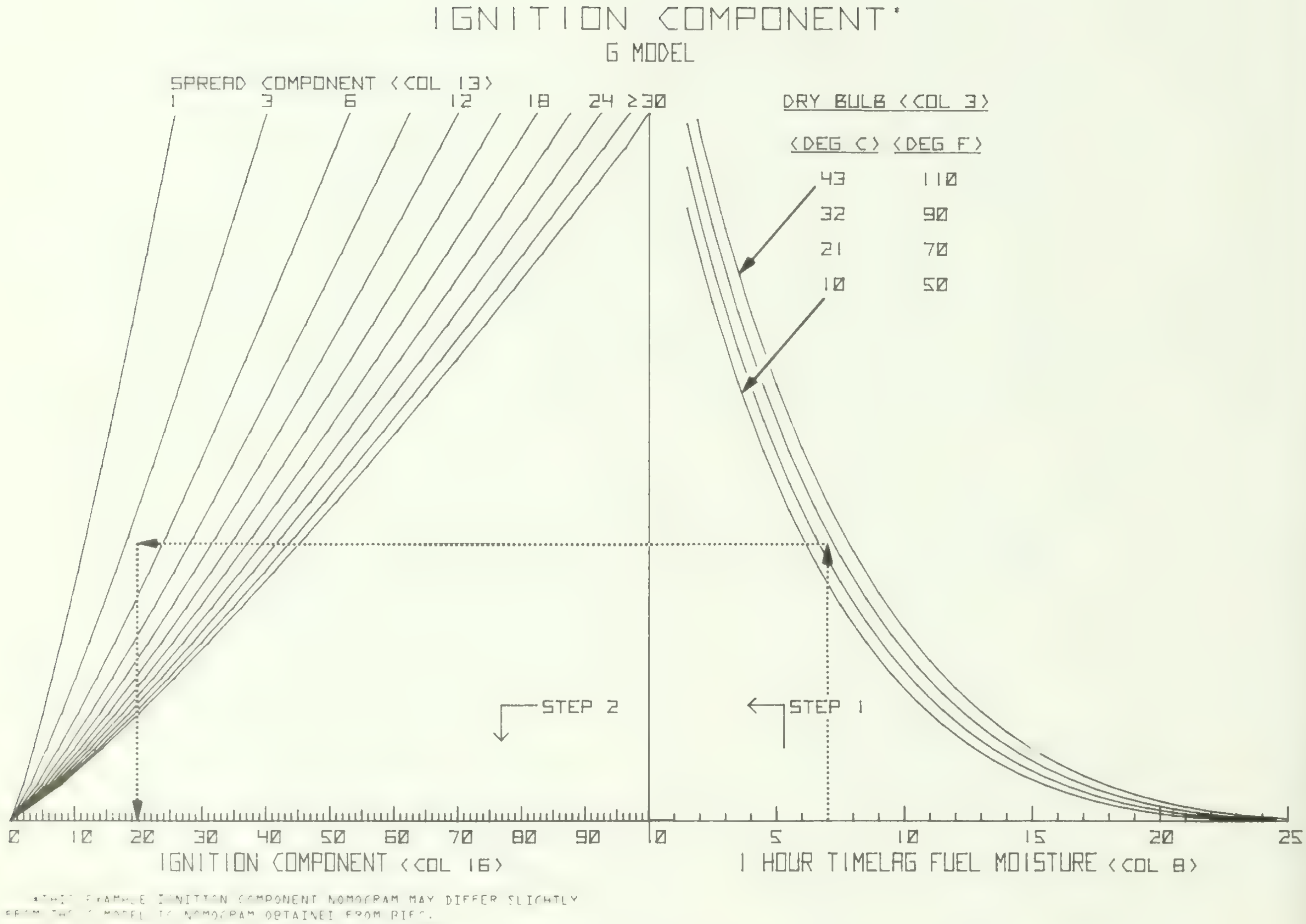


Figure 5.--An example computation of the ignition component illustrating interpolation procedures.

SPECIAL INSTRUCTIONS

The following special instructions and rules are keyed to specific computation steps (nomograms). The steps correspond to the sequence followed in calculating the fire-danger ratings. The column numbers on the nomograms refer to the recording-computation form (10-Day Fire Danger and Fire Weather Record).

100-h TL Fuel Moisture (Column 36)

--If yesterday's 100-h TL FM exceeds 44 percent, use 44 percent.

--Record to the nearest whole percent.

Today's 1,000-h Boundary Value (Column 37)

--Record to the nearest whole percent.

--Average every seventh day and enter in column 38.

Change in 1,000-h TL Fuel Moisture (Column 39)

--Use this nomogram every seventh day.

--Be careful to note whether the change in the 1,000-h TL FM is (+) or (-) and record with the proper sign to the nearest whole percent.

--Add this value to the 1,000-h TL FM at the beginning of the 7-day period to obtain the current 1,000-h TL FM and record the answer in column 40.

Live Fuel Model Nomograms

Three nomograms are available to calculate the moisture contents of the three classes of live fuels: PERENNIAL HERBS AND FORBS, ANNUAL HERBS AND FORBS, and WOODY SHRUBS. General instructions follow. Differences are addressed in the instructions for specific nomograms.

General Instructions

A. Use either the nomogram for the annual herbs and forbs, or the nomogram for the perennial herbs and forbs. You *cannot* use a combination of the two.

B. The 1,000-h TL FM is used to calculate the woody fuel moisture, but the moisture content of herbaceous fuels depends on the X1000 moisture value.

C. The X1000 moisture value is set equal to the 1,000-h TL FM at greenup in the spring, or at midseason flush, as sometimes occurs in the desert areas.

D. Greenup is specified by the user. Two criteria should be adhered to: (1) Wait until the greening process is well established; and (2) declare greenup at the beginning of a 7-day cycle used to calculate the 1,000-h TL FM.

E. The live herbaceous fuel moistures are calculated from greenup until curing is complete either because the moisture content of the herbaceous fuels decreases to 30 percent or a freeze causes curing. From that time until the next greenup, that moisture content equals the 1-h TL FM.

F. The woody fuel moisture nomogram is used from greenup until the plants become dormant, usually the result of cold weather. After a freeze, the woody fuel moisture is set to the lesser of (1) the last value computed, or (2) the pregreen woody fuel moisture. Select the appropriate pregreen woody moisture for your climate class from the following:

Climate class	*Pregreen woody fuel moisture (Percent)*
1	50
2	60
3	70
4	80

This value is to be used until the next greenup. For example, you are using climate class 3 and a hard freeze occurs on October 10. If the woody fuel moisture was computed as 90 percent on October 9, decrease it to 70 percent on October 10. Use 70 percent for the remainder of the fire season. But if the computed woody fuel moisture was 60 percent on October 9, use 60 percent for the remainder of the fire season.

Woody Fuel Moisture (Column 41)

A. *Prior to spring greenup.*--Between the time fire weather observations are started in the spring and greenup, use the pregreen woody fuel moisture corresponding to your climate class.

B. *Computing woody fuel moistures.*--Begin computing woody fuel moistures the day you specify greenup. Use the current 1,000-h TL FM. Every seventh day thereafter, compute and record the woody fuel moisture to the nearest 10 percent. Note that the maximum fuel moisture is 200 percent; the minimum, 50 percent.

Herb. Fuel Moisture (Column 43)

A. *Prior to spring greenup.*--Make the following entries in the 10-Day Fire Danger and Fire Weather Record:

1. Record "C" (cured) for Herb. Veg. Condition (column 9).
2. Use the 1-h TL FM (column 8) for Herb. Fuel Moisture. Skip to the 10-h TL FM calculation.

B. *At greenup (spring or midseason flush).*--On the day you specify greenup (it should be at the beginning of a 7-day cycle for the 1,000-h TL FM calculation), make the following entries on the 10-Day Fire Danger and Fire Weather Record:

1. Enter "G" (green) for Herb. Veg. Condition (column 9) on that dateline and that dateline *only*.

2. Set the value of X1000 (column 42) equal to the 1,000-h TL FM value on that dateline (Column 40).

Make the initial Herb. Fuel Moisture calculation using the appropriate nomogram.

C. *After greenup*.--Column 9 (Herb. Veg. Condition) should be left blank until a second or third flush of new growth is observed or until these plants cure. Curing can occur through natural drying or because of a freeze. If curing occurs because of a freeze, enter an "F" in column 9; if it occurs through drying, enter a "C." If a "C" or an "F" has been recorded or the Herb. Fuel Moisture is less than 30 percent, use the 1-h TL FM for the Herb. Fuel Moisture and the Fine Fuel Moisture for the remainder of the season or until the next greenup.

10-h TL Fuel Moisture (Column 7)

--If snow or ice covers the 1/2-inch fuel moisture sticks, remove it. If it is raining at basic observation time, shake the excess water from the sticks. Weigh the sticks to the nearest gram and record this value in column 6. Use the nomogram to correct the reading for stick age. Record this 10-h TL FM value to the nearest percent.

--If the 1/2-inch fuel moisture sticks are not used, compute using the procedure in appendix B.

When It Is Raining At Basic Observation Time

--If it is raining (state of weather codes 5, 6, or 7), or if there is snow or ice on the ground, make the following entries on the 10-Day Fire Danger and Fire Weather Record:

Item	Entry	Column
1-h TL Fuel Moisture	30+	8
Herb. Veg. Condition	98	9
Fine Fuel Moisture	30+	10
Spread Component	0	13
Energy Release Component	0	14
Burning Index	0	15
Ignition Component	0	16
~~Lightning Occurrence Index~~	~~0~~	~~18~~
Man-Caused Occurrence Index	0	20
Fire Load Index	0	21

1-h TL Fuel Moisture (Column 8)

--If the 10-h TL FM has not been obtained by weighing fuel sticks, compute it by the optional method in appendix B.

--Record the 1-h TL FM to the nearest whole percent.

Fine Fuel Moisture (Column 10)

--If the Herb. Veg. Condition (column 9) is cured (C) or cured by freezing (F), use the value from column 8 (1-h TL FM) for the Fine Fuel Moisture.

--If the 1-h TL FM is high enough that it is impossible to intersect the appropriate Herb. Fuel Moisture curve in step 1 (the correct value lies too far to the right on the x-axis), use the highest possible value for the Fine Fuel Moisture, as indicated on the left half of the x-axis.

Example: When using the G fuel model, if the 1-h TL FM is 22 percent and the Herb. Fuel Moisture is higher than about 140 percent, no intersection exists. In such cases, the Fine Fuel Moisture should be recorded as 25 percent.

--At no time should the Fine Fuel Moisture be less than the 1-h TL Fuel Moisture (column 8).

--Record Fine Fuel Moisture to the nearest whole percent.

Spread Component (Column 13)

--The Wind Slope Factor is not recorded on the computation form, but it is carried forward to step 3 (second Spread Component nomogram).

--Note that the windspeed can be entered in miles per hour using the upper scale on the x-axis or in kilometers per hour using the lower scale.

Energy Release Component (Column 14)

--The value called "B" from step 2 is carried forward to step 3 (second Energy Release Component nomogram).

Burning Index (Column 15)

--None.

Ignition Component (Column 16)

--The IC equals zero when the SC is zero.

--In step 1 the dry-bulb temperature can be entered in degrees Fahrenheit or in degrees Centigrade.

Lightning Risk (Column 17)

--If the Lightning Activity Level (column 35) is 1, record the LR and the LOI (column 18) as zero. Skip to the calculation of MCR.

--If the LAL is 6, record 100 for the LR and LOI and skip to the MCR calculation.

Lightning-Caused Fire Occurrence Index (Column 18)

--If the LAL is 1, the LOI is zero; if the LAL is 6, the LOI is 100 (Deeming and others 1977).

Man-Caused Risk (Column 19)

--None (Deeming and others 1977).

Man-Caused Fire Occurrence Index (Column 20)

--Two nomograms are provided; one for use when the IC is less than or equal to 30, the other when the IC is greater than 30 percent.

Fire Load Index (Column 21)

--If the BI is greater than 140, use 140; if the sum of the LOI and MCOI is greater than 100, use 100.

COMPUTATIONAL PROCEDURES: A WORKED EXAMPLE AND EXERCISE

A complete set of nomograms for fuel model G and two sample 10-Day Fire Danger and Fire Weather Record forms are provided (pages 16-41). The solutions of the fuel moistures, components, and indexes for the first day are shown with dashed lines on the nomograms. Work through the example for the first day to familiarize yourself with the procedures. Use the remaining 9 days of weather data for practice, recording your answers on the first form. Check your results against the entries on the second form. Because of rounding differences, you are correct if your answers are within ±1 point of those on the answer sheet.

You need only compute the man-caused risk for July 3 and 4. The completed MCR worksheets for July 1 and 2 and the partially completed MCR worksheets for July 3 and 4 are provided.

To get started, assume the following conditions for June 30, 1975:

--Fuel model = G
--Slope class = 3
--Lightning risk scaling factor (LRSF) = 0.85
--Man-caused risk scaling factor (MRSF) = 0.18
--100-h TL FM = 17 percent
--1,000-h TL FM = 14 percent
--X1000 = 14 percent
--Herbaceous vegetation condition (column 9). No midseason flush of growth occurs during this sample exercise. Leave blank.
--Age of fuel moisture sticks = 3 months
--Yesterday's lightning fire occurrence index = 50

Assume the previous 7-day period for calculating the 1,000 h TL FM ended on July 1. The next 7-day period starts July 2 and ends July 8. After completing this exercise, use the form in the back of this manual to order a working set of nomograms for each fuel model you will use.

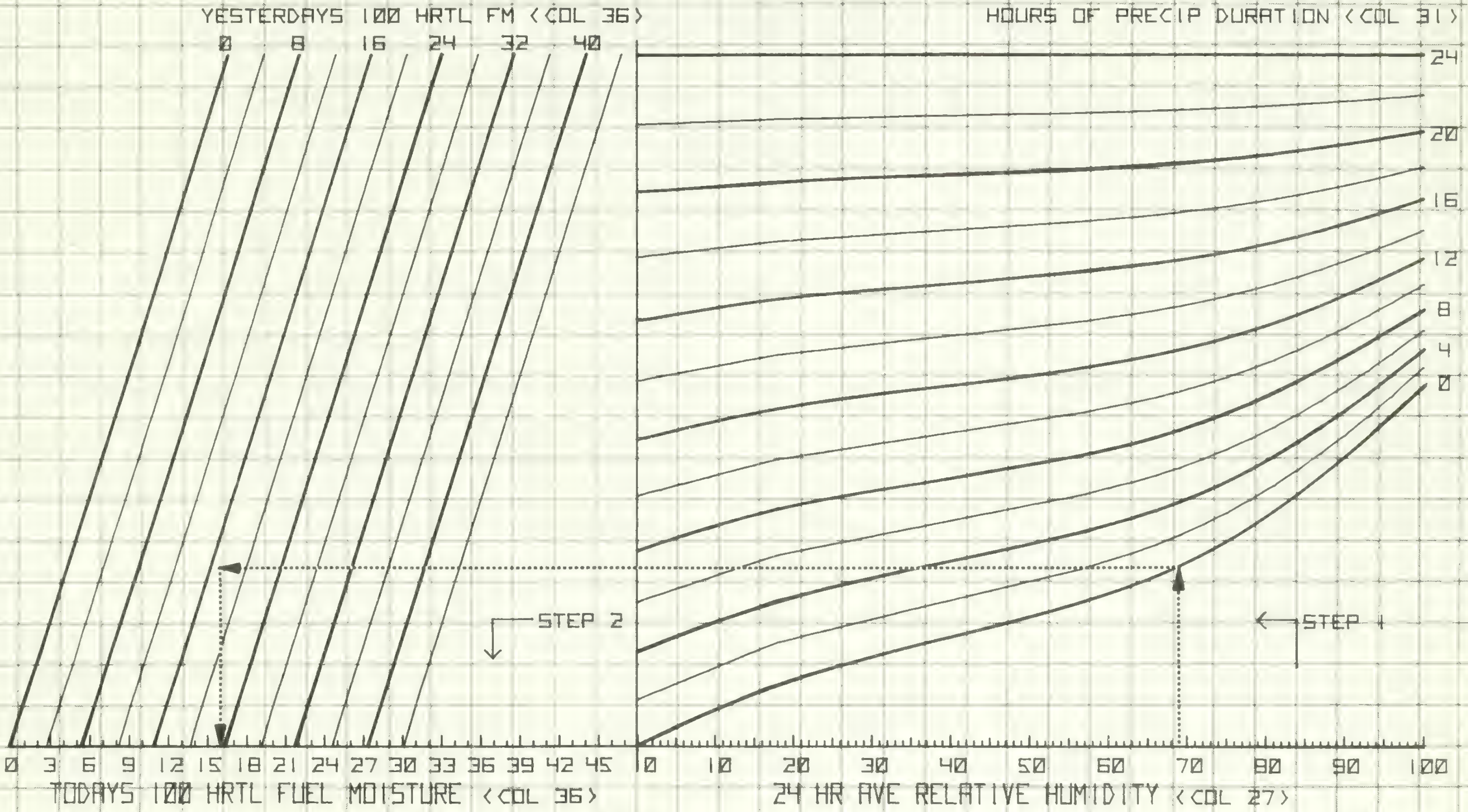
10 DAY FIRE DANGER AND FIRE WEATHER RECORD	Agency FOREST SERVICE		Unit LIBBY DISTRICT		Station Name LIBBY	Station Number 240107
	Station Elevation 2070	Fuel Model G ~~Annual or~~ Perennial P	Slope Class 3	Climate Class 3 Basic Obs Time (LST) 1400	Period of Record (Month, Day, Year) From 7/1/75	To 7/10/75

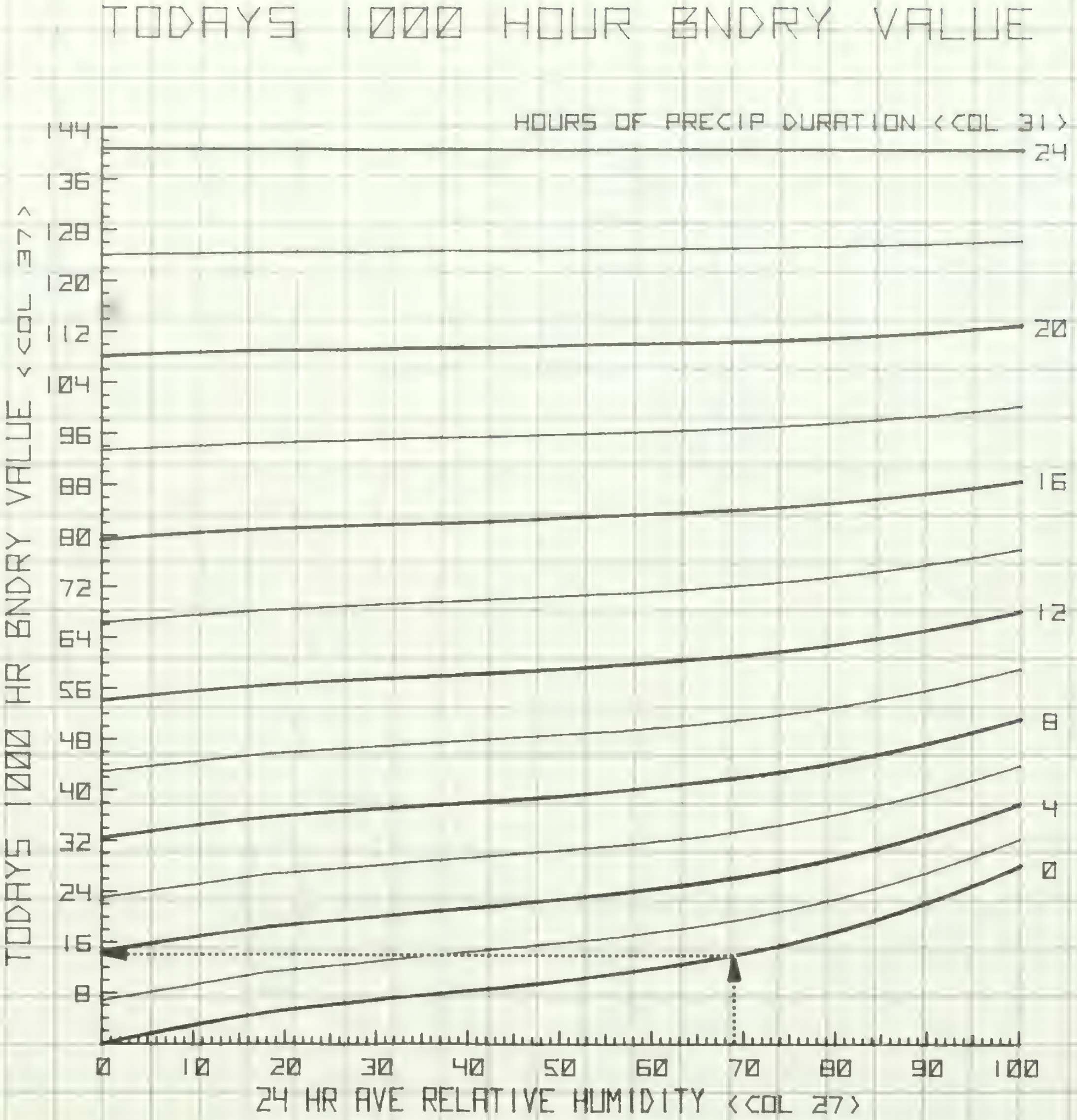
Day of Month	State of Weather	Temperature: Dry Bulb	Temperature: Wet Bulb	Relative Humidity	Measured Fuel Sticks	10-Hr TL Fuel Moisture	1-Hr TL Fuel Moisture	Herb. Veg. Condition	Fine Fuel Moisture	Wind: Direction	Wind: Speed	Burning Index: Spread Component	Burning Index: Energy Release Component	Burning Index	Ignition Component	Occurrence Indexes: Lightning Risk	Occurrence Indexes: Lightning Occurrence Index	Occurrence Indexes: Man-caused Risk	Occurrence Indexes: Man-caused Occurrence Index	Fire Load Index	Observer / Checked By / Remarks
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
1	1	79		39	10	13	7		13		2	4	33	28	20	11	18	10	2	24	½" FM STICKS
2	2	81		32	7						2							19			ARE 3 MOS. OLD
3	3	69		34	8						2										
4	6	55		94	21			98			1										
5	3	61		69	28						1							20			
6	3	64		53	19						1							13			
7	1	72		40	11						4							15			
8	0	78		41	9						2							12			
9	6	52		100	21			98			2							23			
10	3	57		67	26						3							25			
31																					

Daily (24 Hour) Data

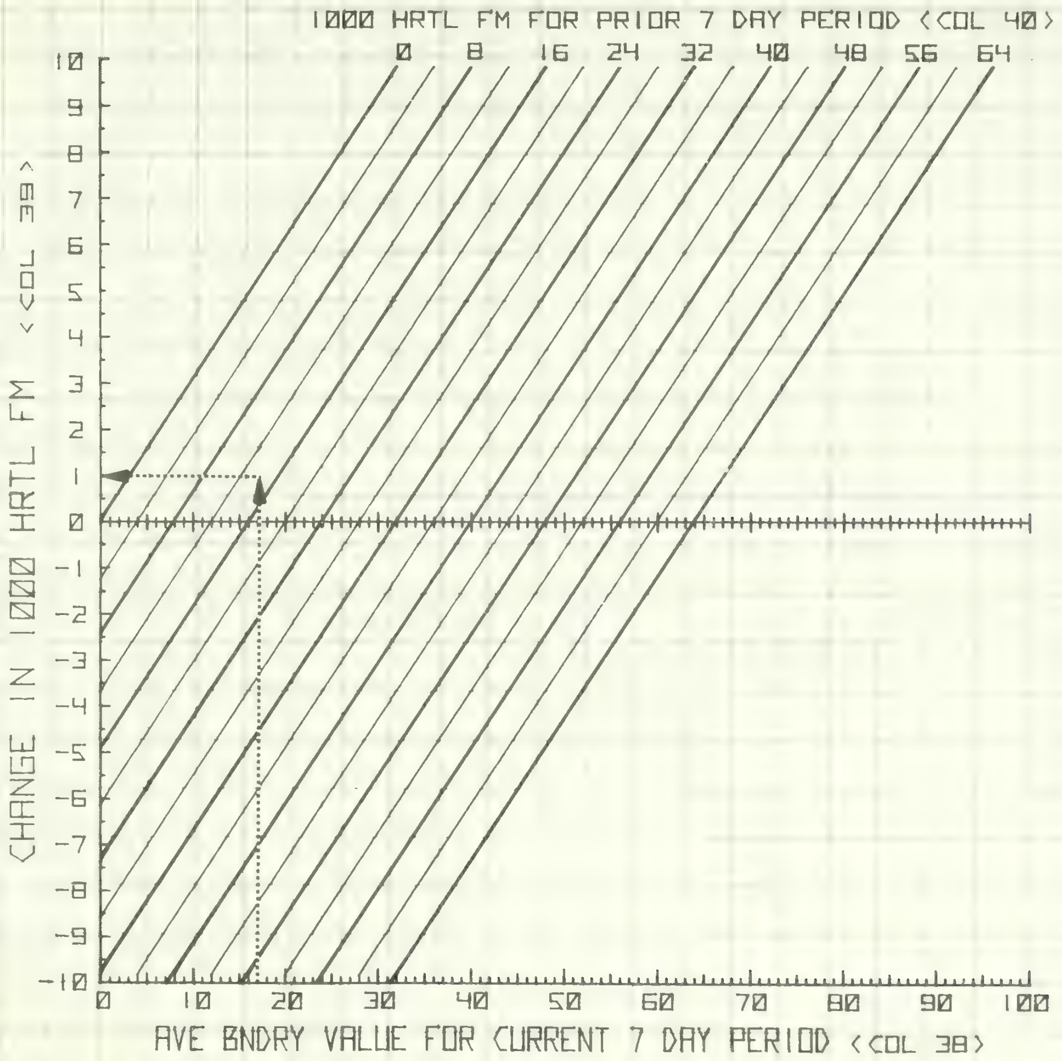
Day of Month	Temperature: Maximum	Temperature: Minimum	Relative Humidity: Maximum	Relative Humidity: Minimum	Relative Humidity: Average	Precipitation: Kind	Precipitation: Begin	Precipitation: Ended	Precipitation: Duration	Precipitation: Amount	Lightning: Began	Lightning: Ended	Lightning: Activity Level	100-Hr TL Fuel Moisture	1000-Hr TL Fuel Moisture: Today's 1000-Hr Bndry Value	1000-Hr TL Fuel Moisture: Average 7 Day Bndry Value	1000-Hr TL Fuel Moisture: Change 1000 Hr Fuel Moisture	1000-Hr TL Fuel Moisture: 1000-Hr TL Fuel Moisture	Living Fuel Moisture: Woody Fuel Moisture	Living Fuel Moisture: X1000 Moisture Value	Living Fuel Moisture: Herb Fuel Moisture	A	B	C	D
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	A	B	C	D
1	79	44	99	39	69				0				2	16	14	17	+1	15	110	14	100				
2	82	40	90	22	56				0				1												
3	84	44	99	20	60				0				1												
4	69	48	99	30	65	5	0500	1300	8	.16			1												
5	61	45	99	69	84	5	0200	1200	10	.32			1												
6	66	46	99	52	76	5	1600	1800	2	.05			1												
7	72	47	99	40	70	6	0800	0900	1	.04			1												
8	78	45	99	40	70				0				4												
9	85	52	99	32	66	6	1300	1800	5	.29			2												
10	76	42	99	67	83	6	1600	1800	2	.12			2												
31																									

100 HOUR TIMELAG FUEL MOISTURE

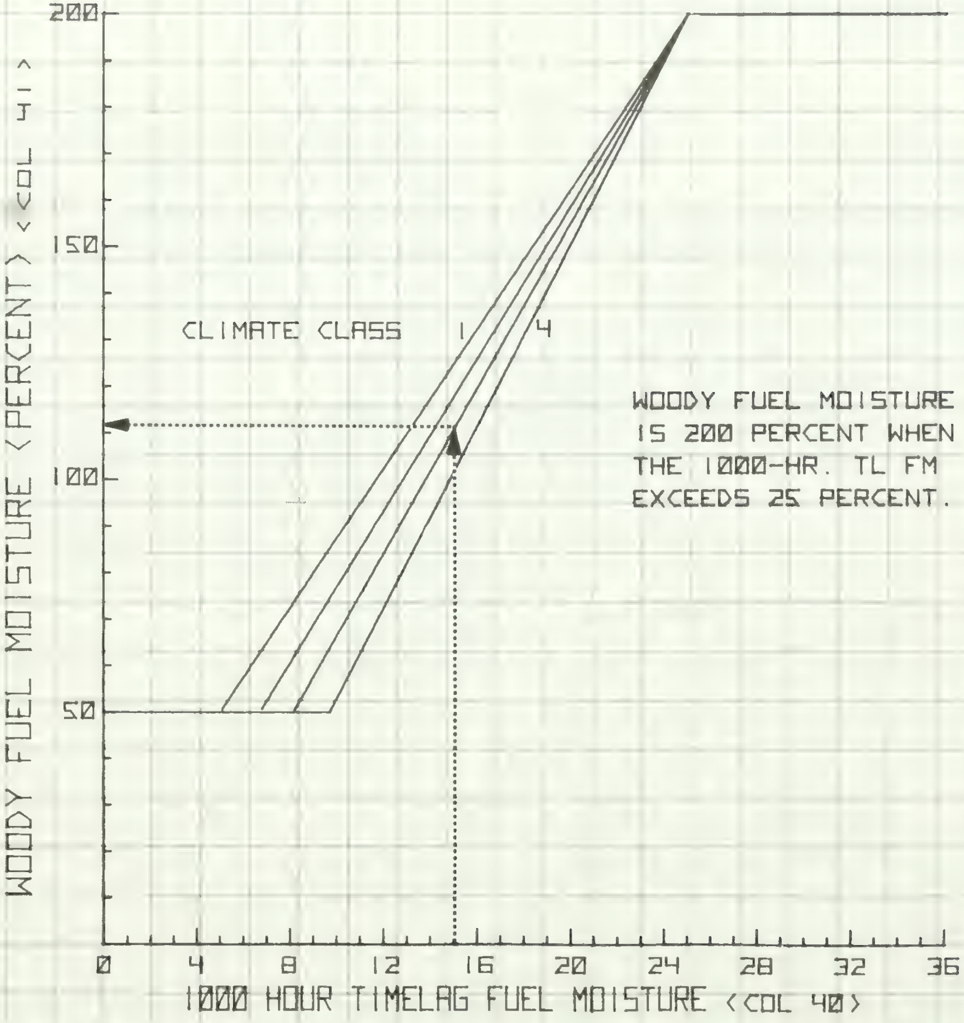



TODAYS 1000 HOUR BNDRY VALUE
HOURS OF PRECIP DURATION <COL 31>
24
20
16
12
8
4
0
TODAYS 1000 HR BNDRY VALUE <COL 37>
144
136
128
120
112
104
96
88
80
72
64
56
48
40
32
24
16
8
0
10
20
30
40
50
60
70
80
90
100
24 HR AVE RELATIVE HUMIDITY <COL 27>

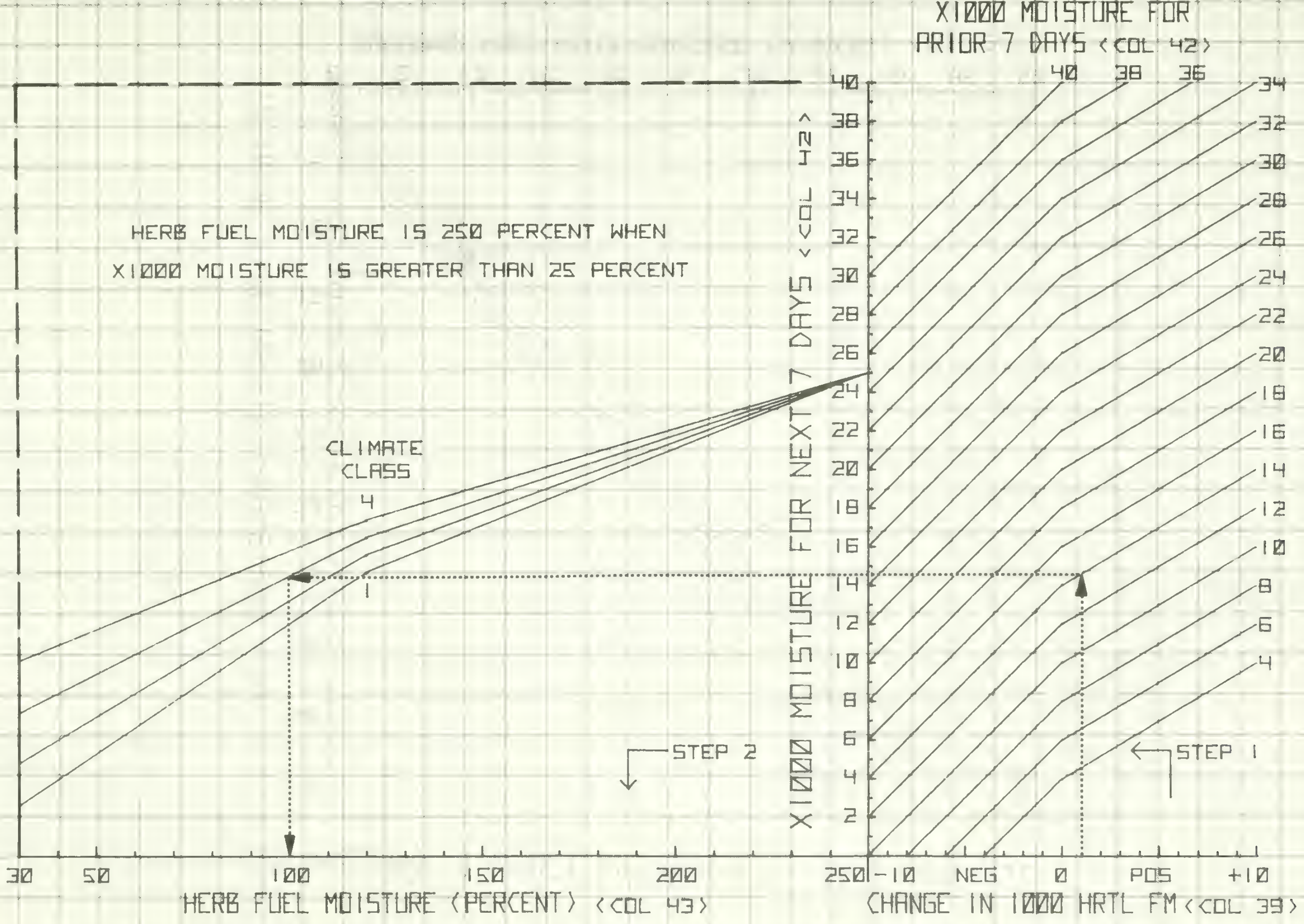
1000 HOUR TIMELAG FUEL MOISTURE



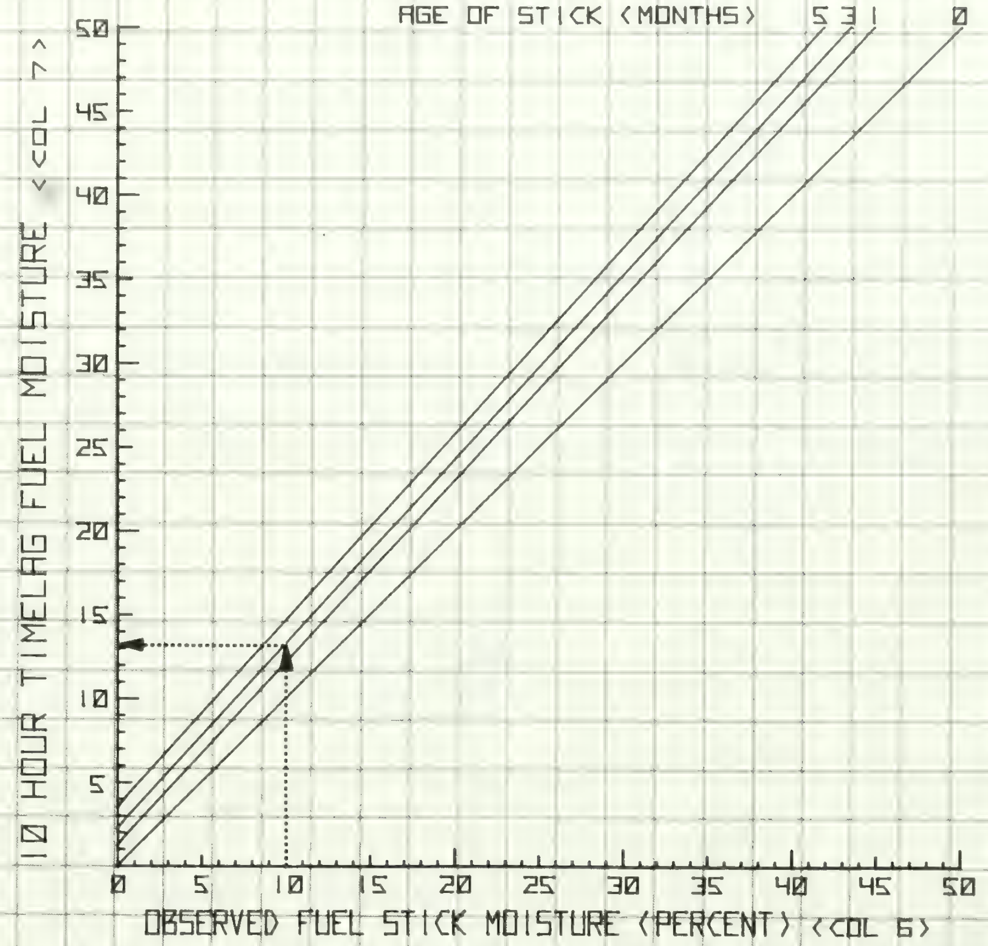
WOODY FUEL MOISTURE



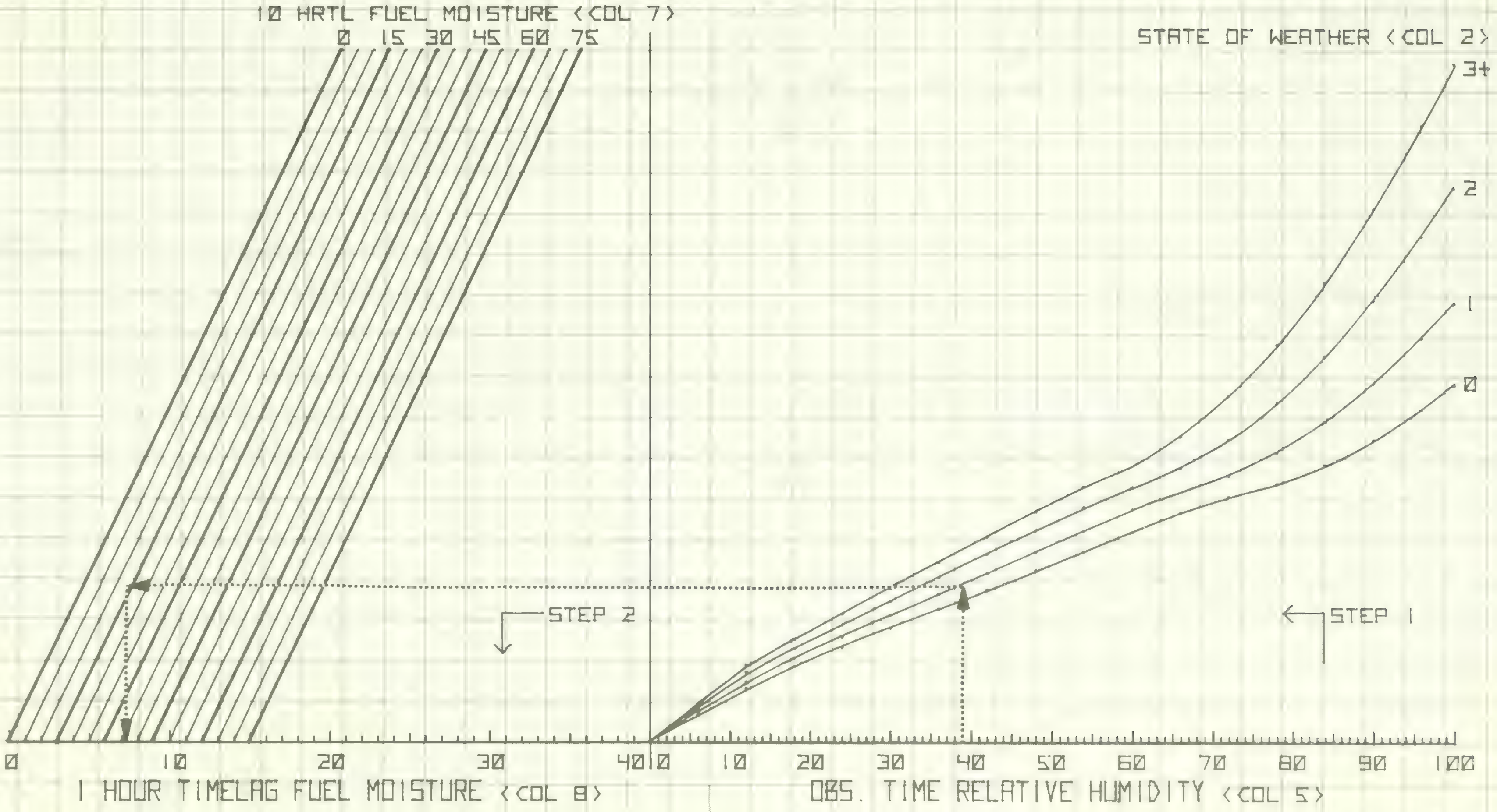
PERENNIAL HERBS AND FORBS



10 HOUR TIMELAG FUEL MOISTURE

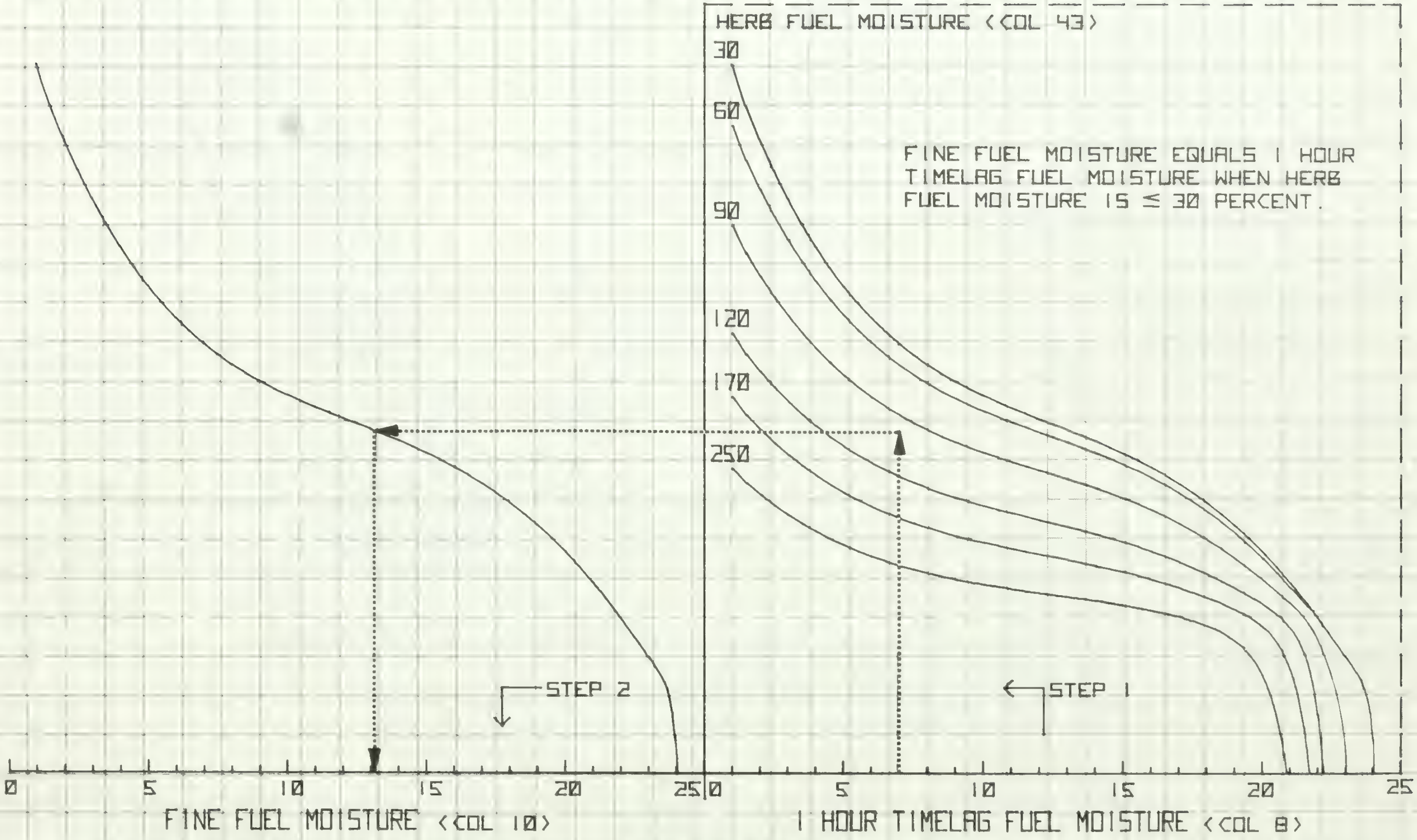


I HOUR TIMELAG FUEL MOISTURE



FINE FUEL MOISTURE

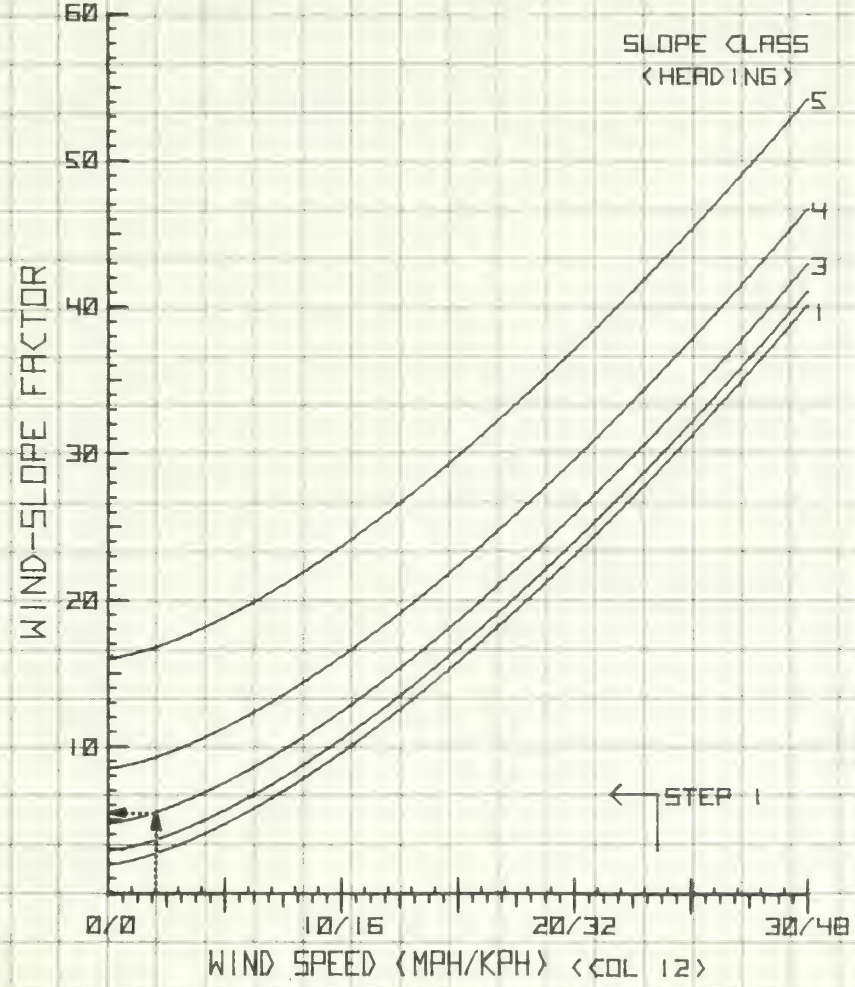
G MODEL



FINE FUEL MOISTURE EQUALS 1 HOUR TIMELAG FUEL MOISTURE WHEN HERB FUEL MOISTURE IS ≤ 30 PERCENT.

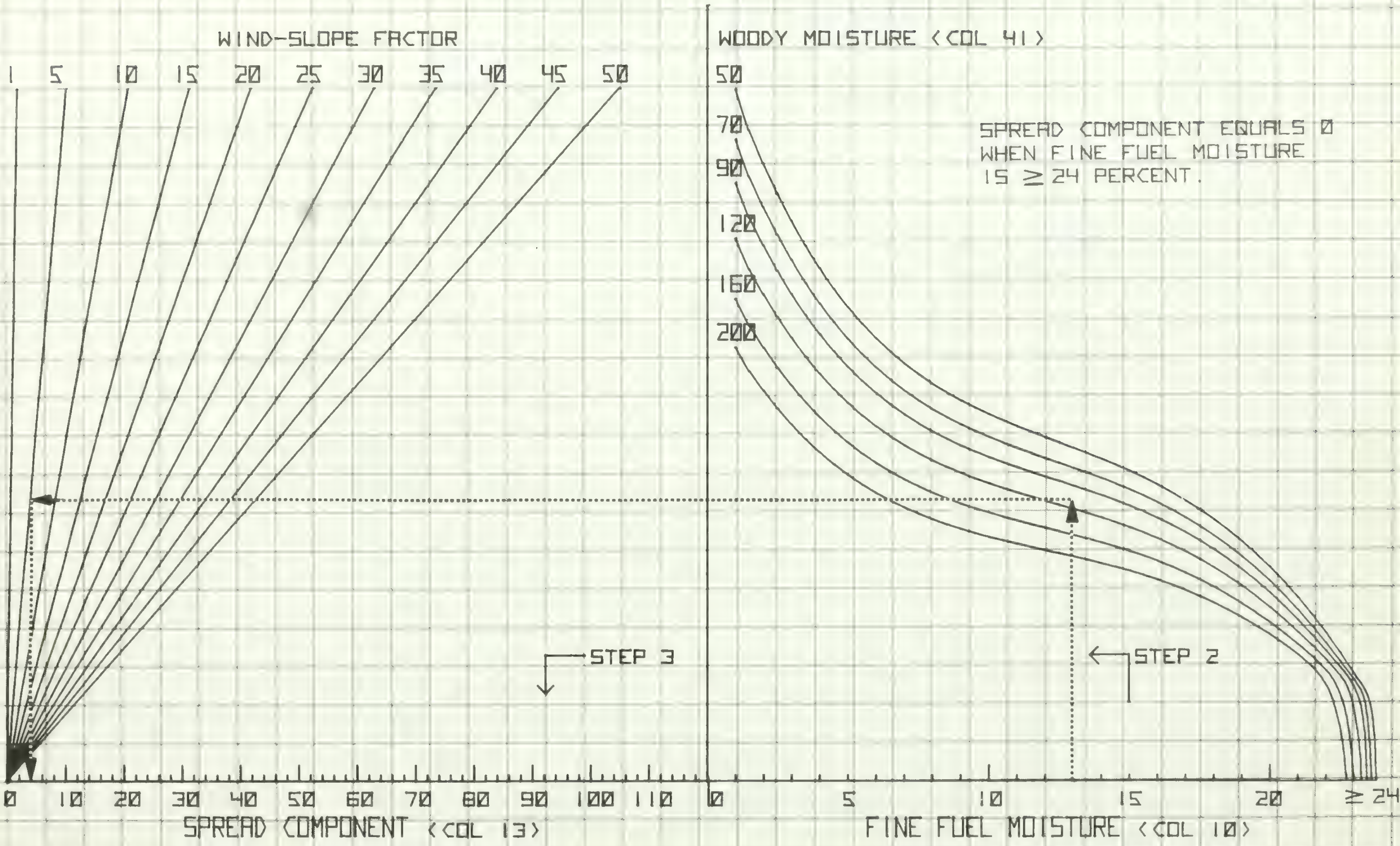
SPREAD COMPONENT

G MODEL



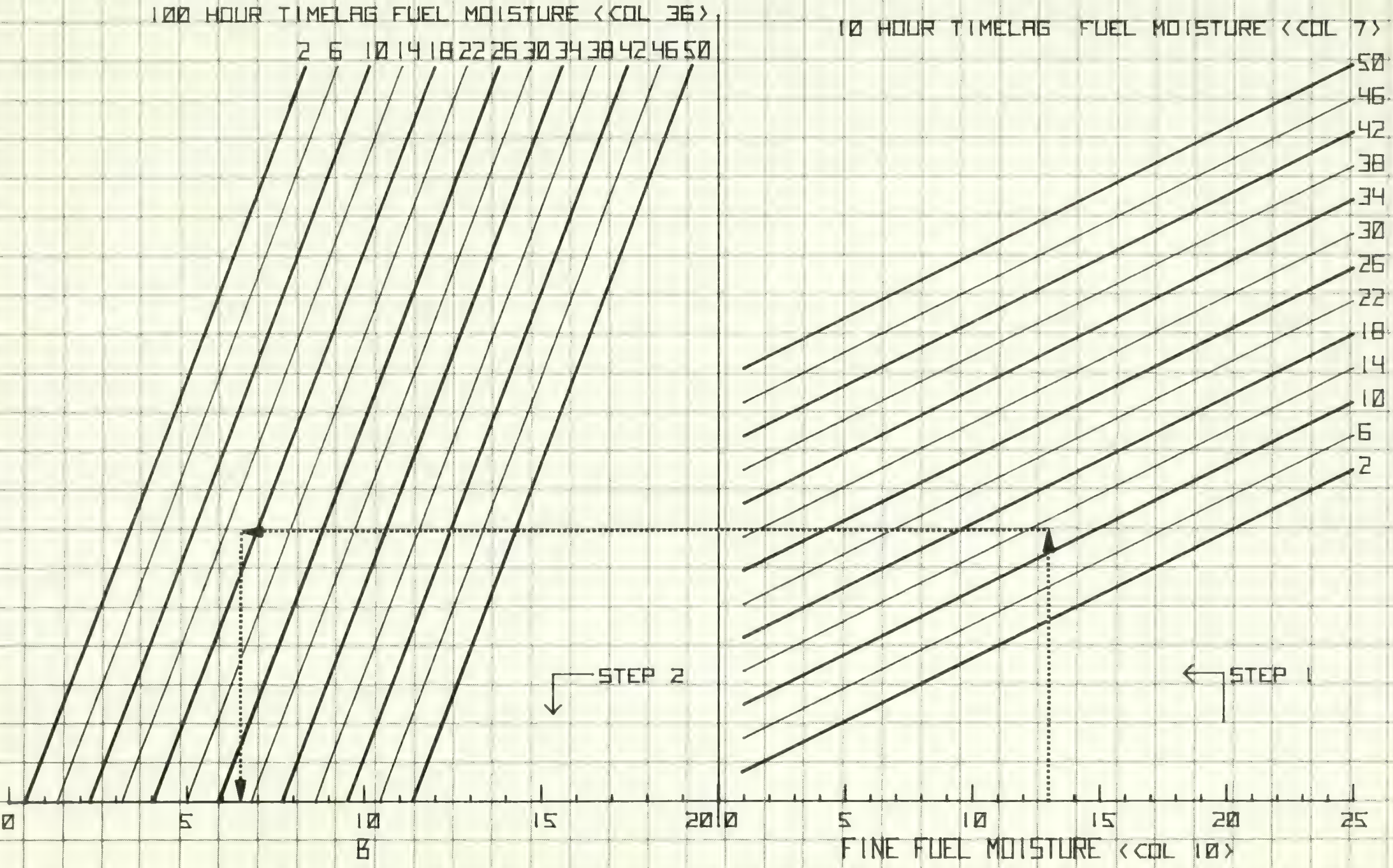
SPREAD COMPONENT

G MODEL



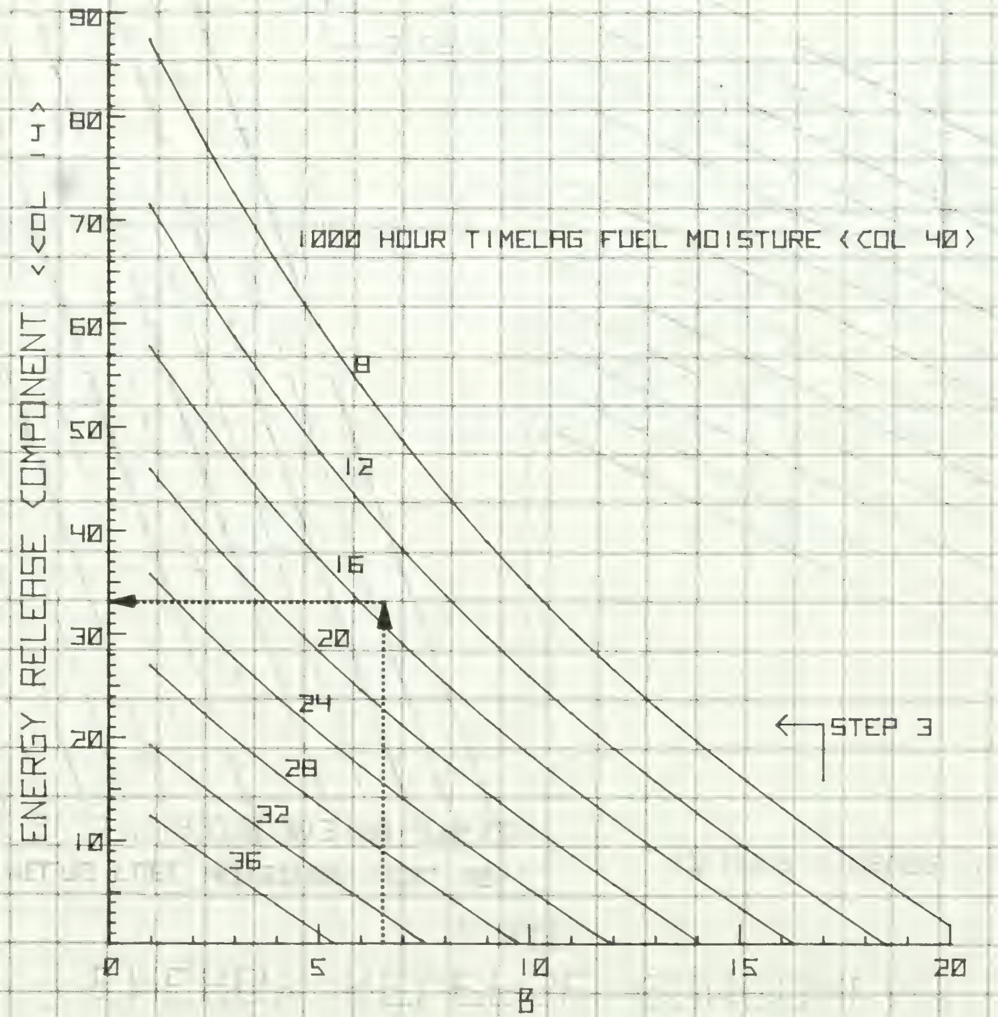
ENERGY RELEASE COMPONENT

G MODEL



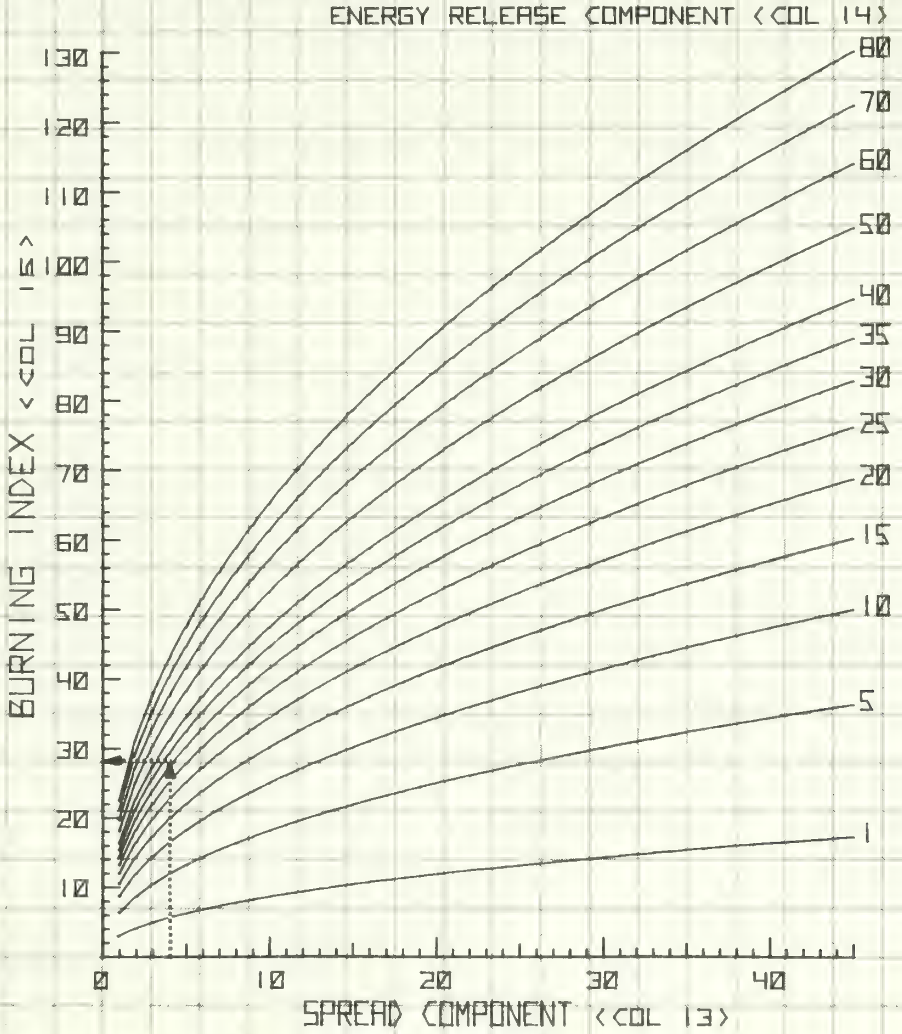
ENERGY RELEASE COMPONENT

G MODEL



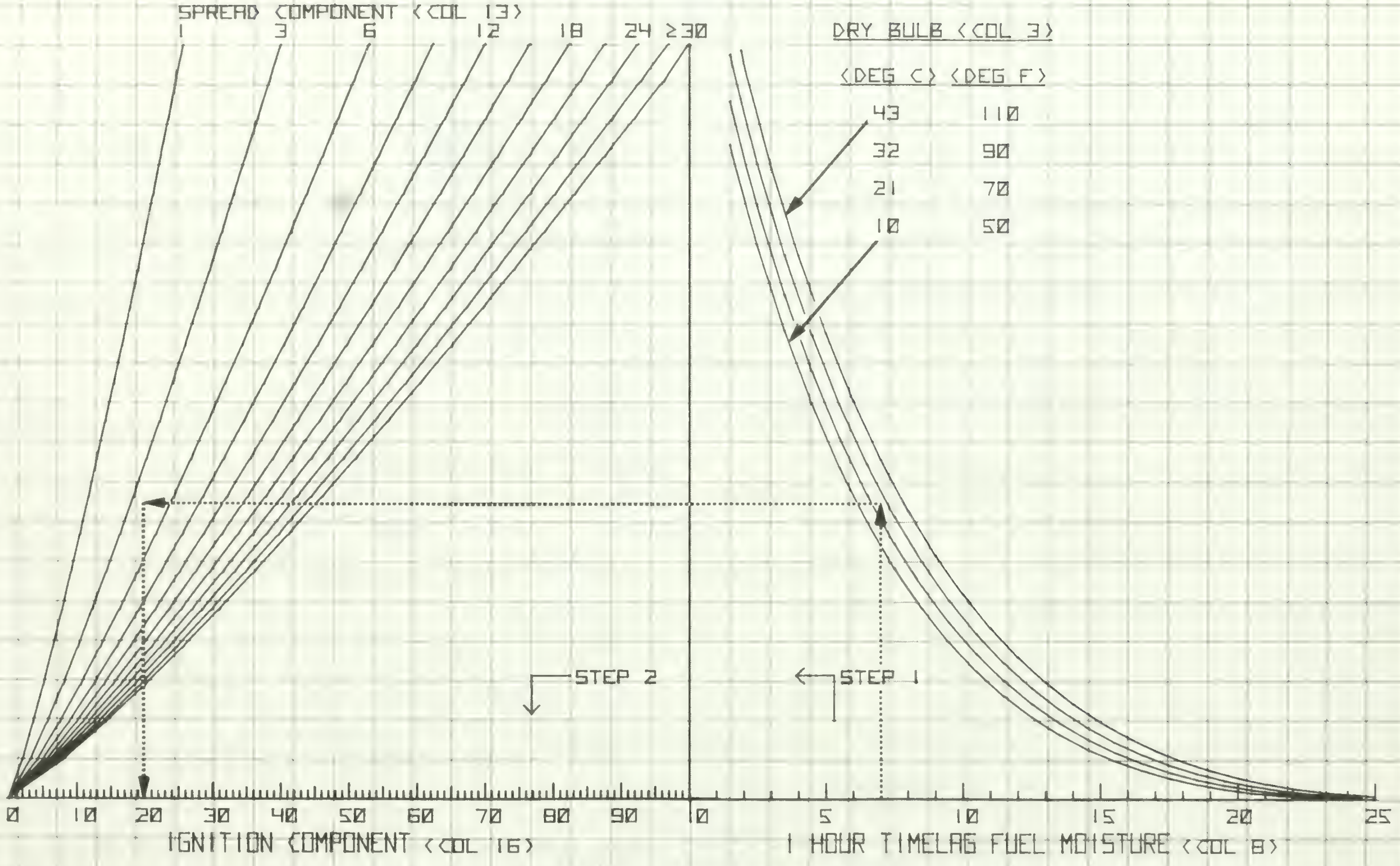
BURNING INDEX

G MODEL



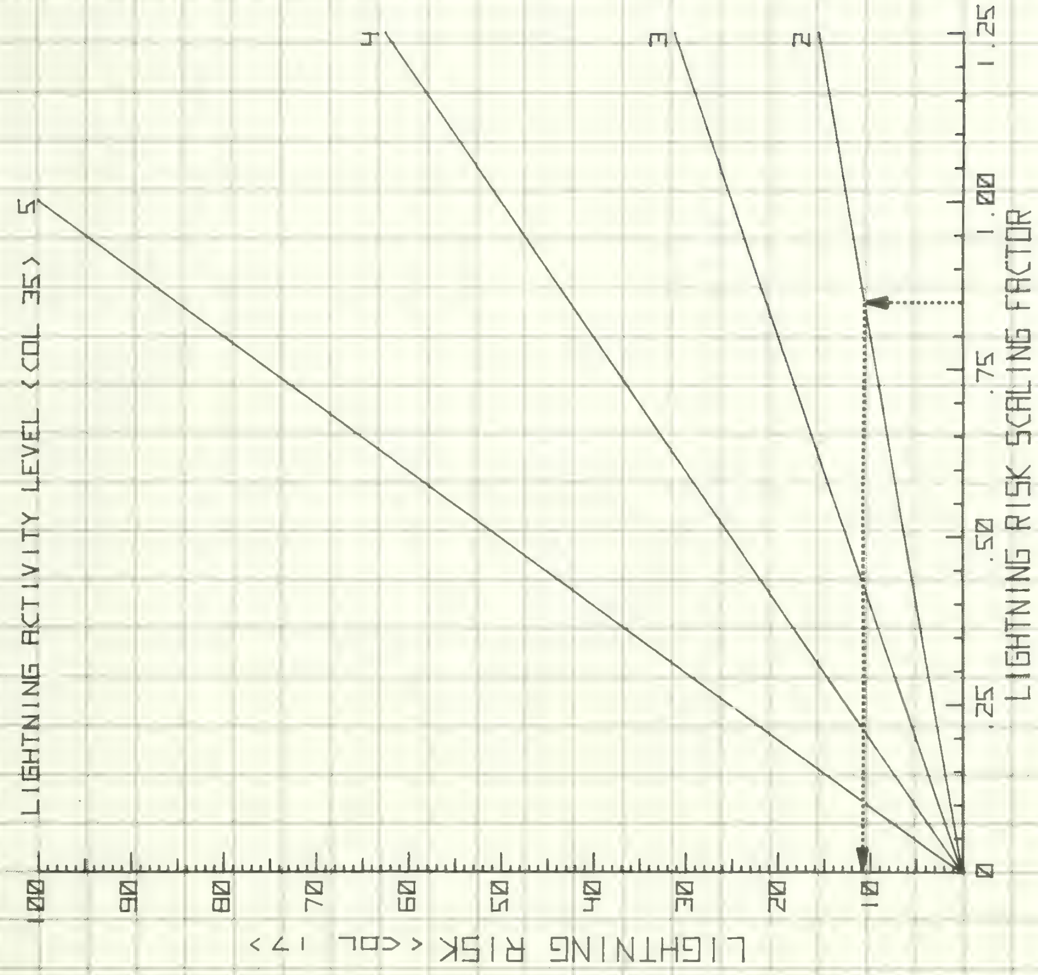
IGNITION COMPONENT*

G MODEL

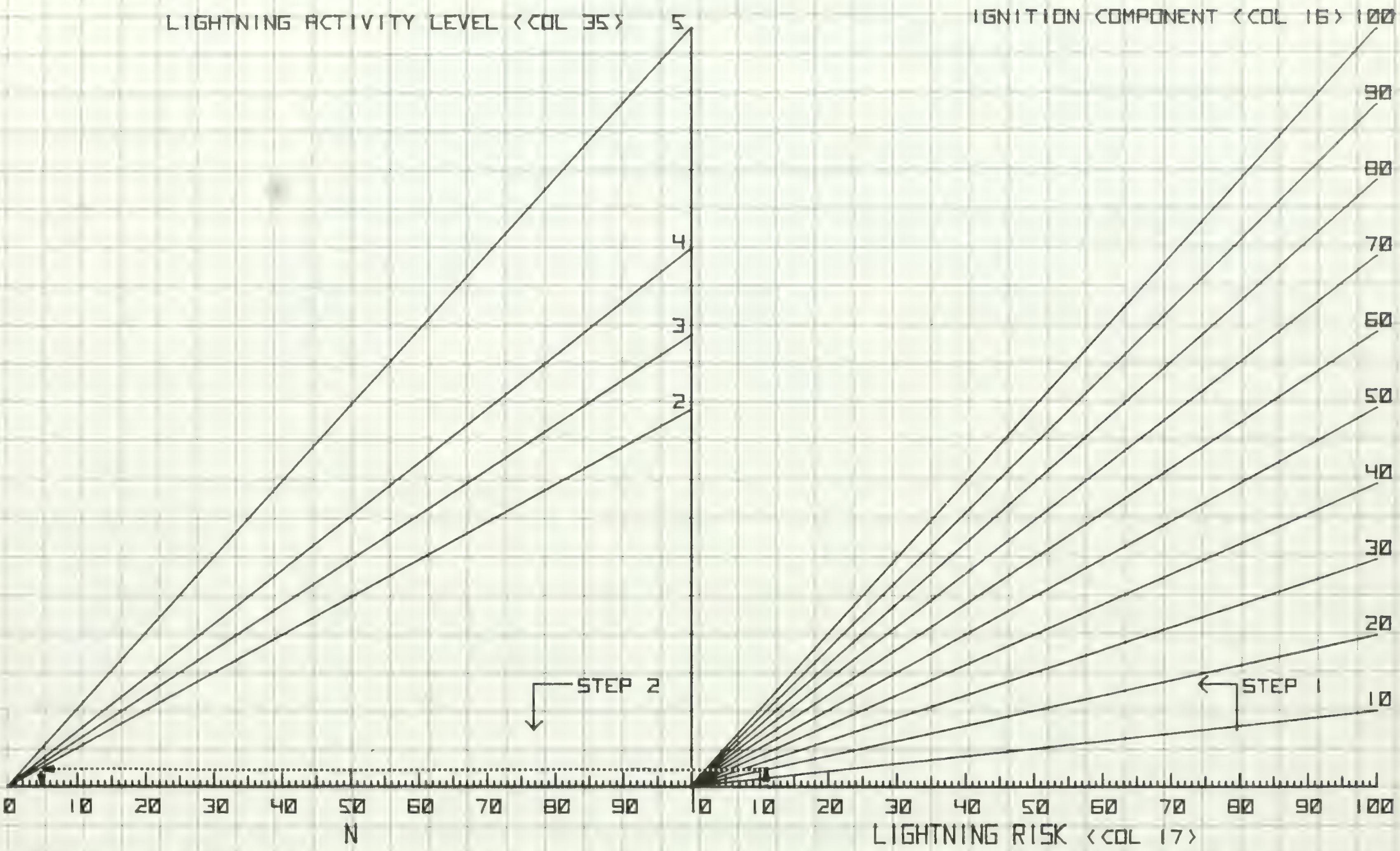


*THIS EXAMPLE IGNITION COMPONENT NOMOGRAM MAY DIFFER SLIGHTLY FROM THE G MODEL IC NOMOGRAM OBTAINED FROM BIFC.

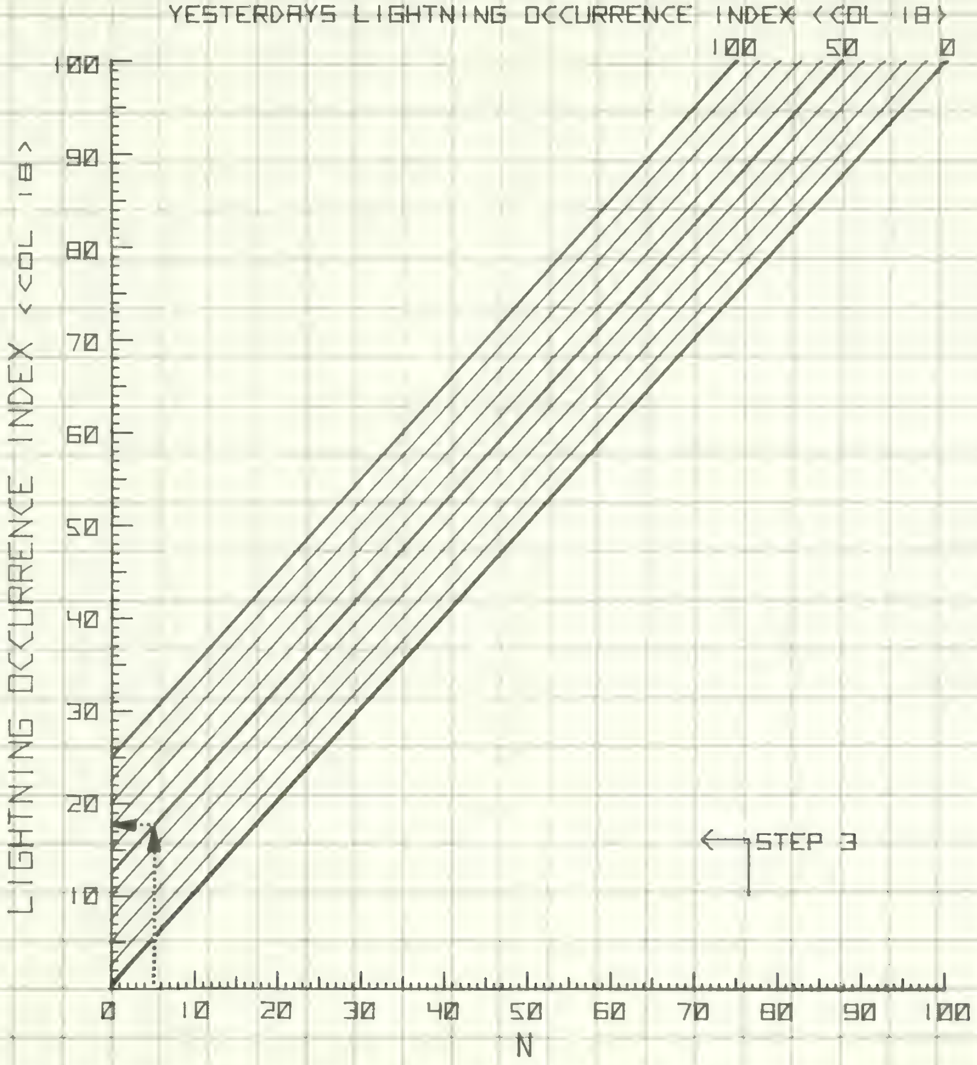
LIGHTNING RISK



LIGHTNING OCCURRENCE INDEX



LIGHTNING OCCURRENCE INDEX



MAN-CAUSED RISK COMPUTATION FORM

Unit LIBBY DISTRICT Date 7/1/75

MCR scaling factor .18 Day of week FRIDAY

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1. EQUIPMENT USE	24	NORMAL	6
2. CAMPFIRES	7	NORMAL	2
3. DEBRIS BURNING	15	NORMAL	4
4. ALL OTHER	8	NORMAL	2
5.			

Total - Unnormalized MC RISK - - - - - - - - - - - - - 14

MCR (E-2) - - - - - - - - - - - - - - - - - - 10

Unit LIBBY DISTRICT Date 7/2/75

MCR scaling factor .18 Day of week SATURDAY

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1. EQUIPMENT USE	12	NORMAL	3
2. CAMPFIRES	23	HIGH	12
3. DEBRIS BURNING	30	NORMAL	7
4. ALL OTHER	9	NORMAL	3
5.			

Total - Unnormalized MC RISK - - - - - - - - - - - - - 25

MCR (E-2) - - - - - - - - - - - - - - - - - - 19

MAN-CAUSED RISK COMPUTATION FORM

Unit LIBBY DISTRICT Date 7/3/75

MCR scaling factor .18 Day of week SUNDAY

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1. EQUIPMENT USE	4	NORMAL	
2. CAMPFIRES	27	HIGH	
3. DEBRIS BURNING	19	NORMAL	
4. ALL OTHER	8	NORMAL	
5.			

Total - Unnormalized MC RISK - - - - - - - - - - - - - ______

MCR (E-2) - ______

Unit LIBBY DISTRICT Date 7/4/75

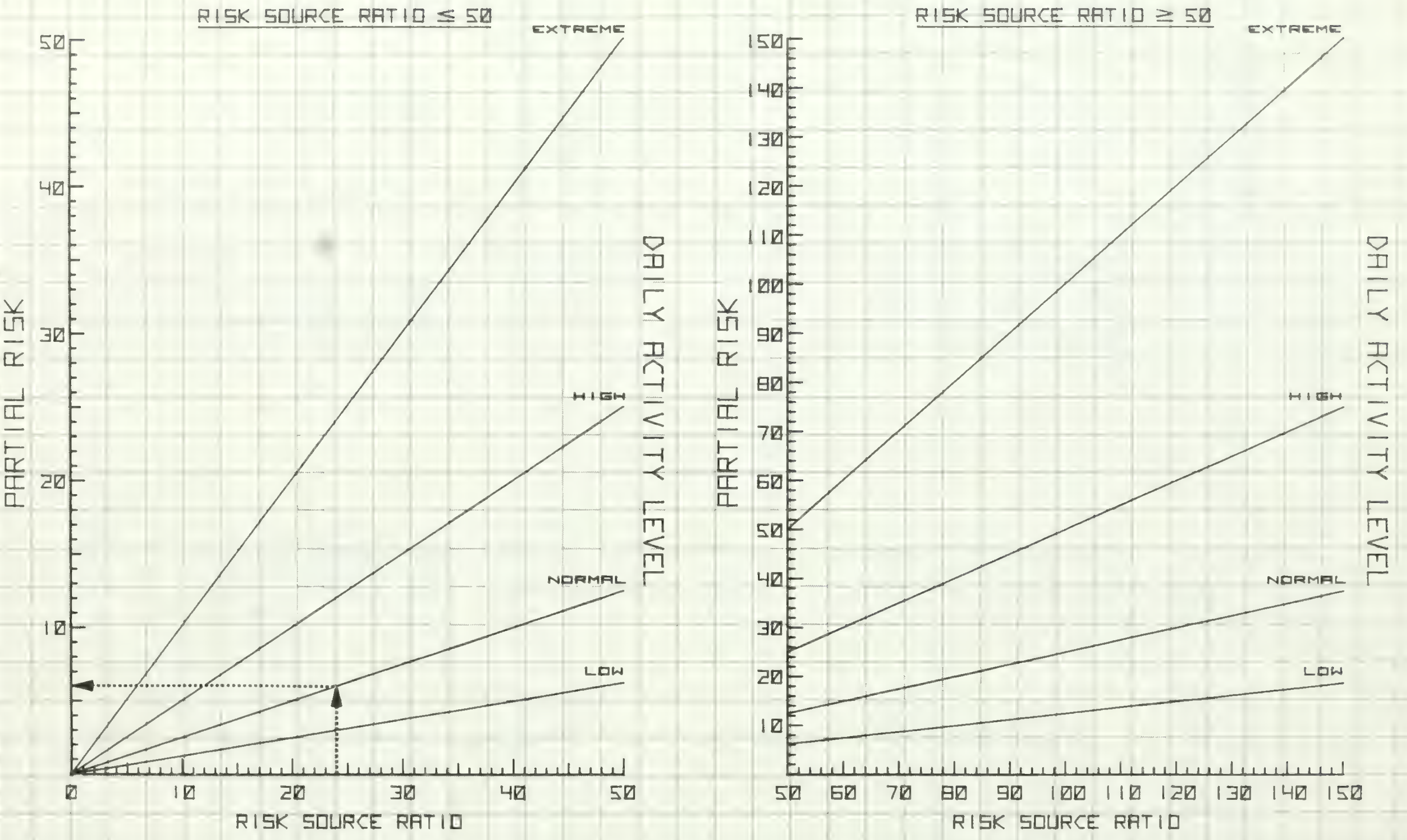
MCR scaling factor .18 Day of week MONDAY

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1. EQUIPMENT USE	26	LOW	
2. CAMPFIRES	12	EXTREME	
3. DEBRIS BURNING	18	NORMAL	
4. ALL OTHER	8	NORMAL	
5.			

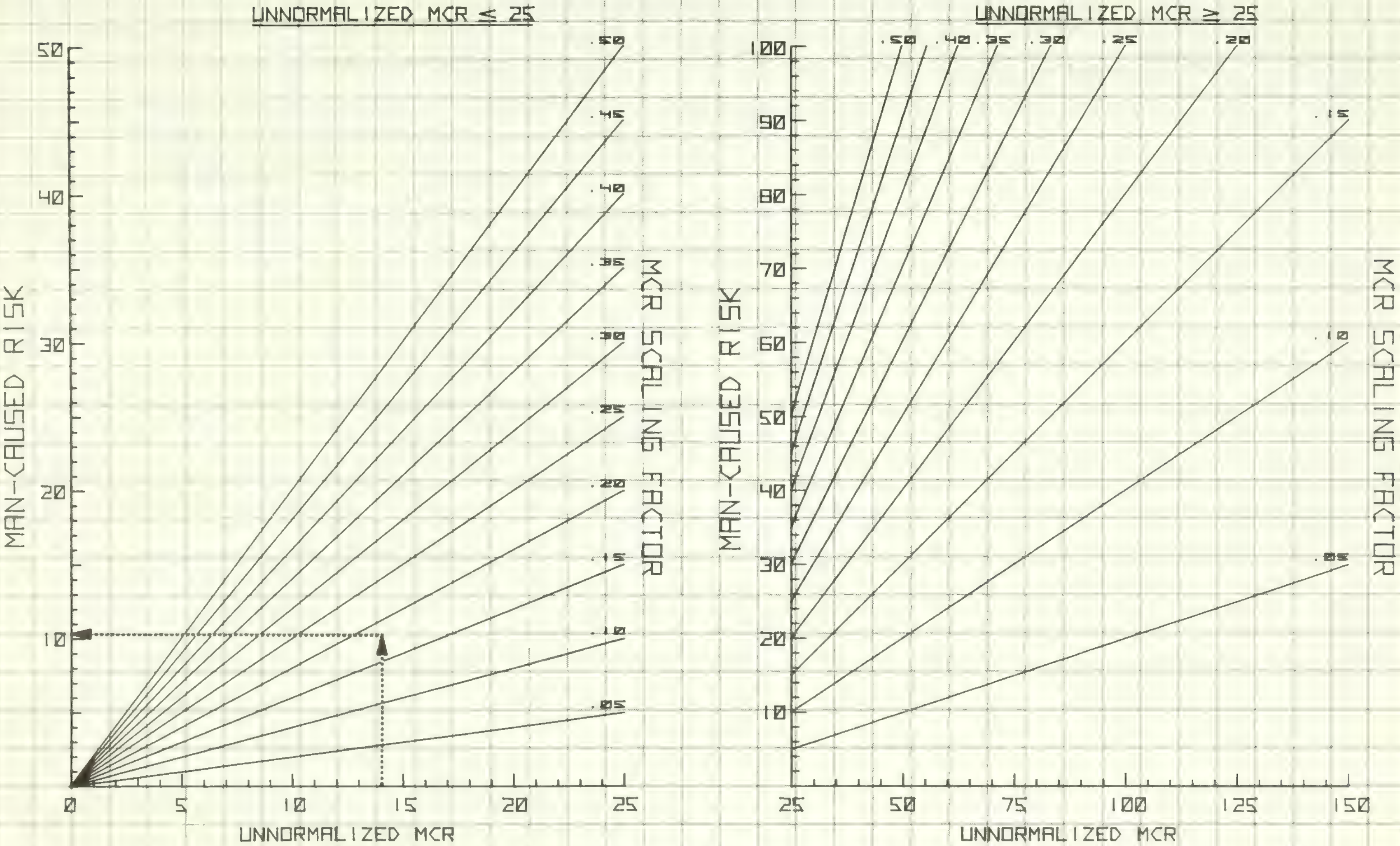
Total - Unnormalized MC RISK - - - - - - - - - - - - - ______

MCR (E-2) - ______

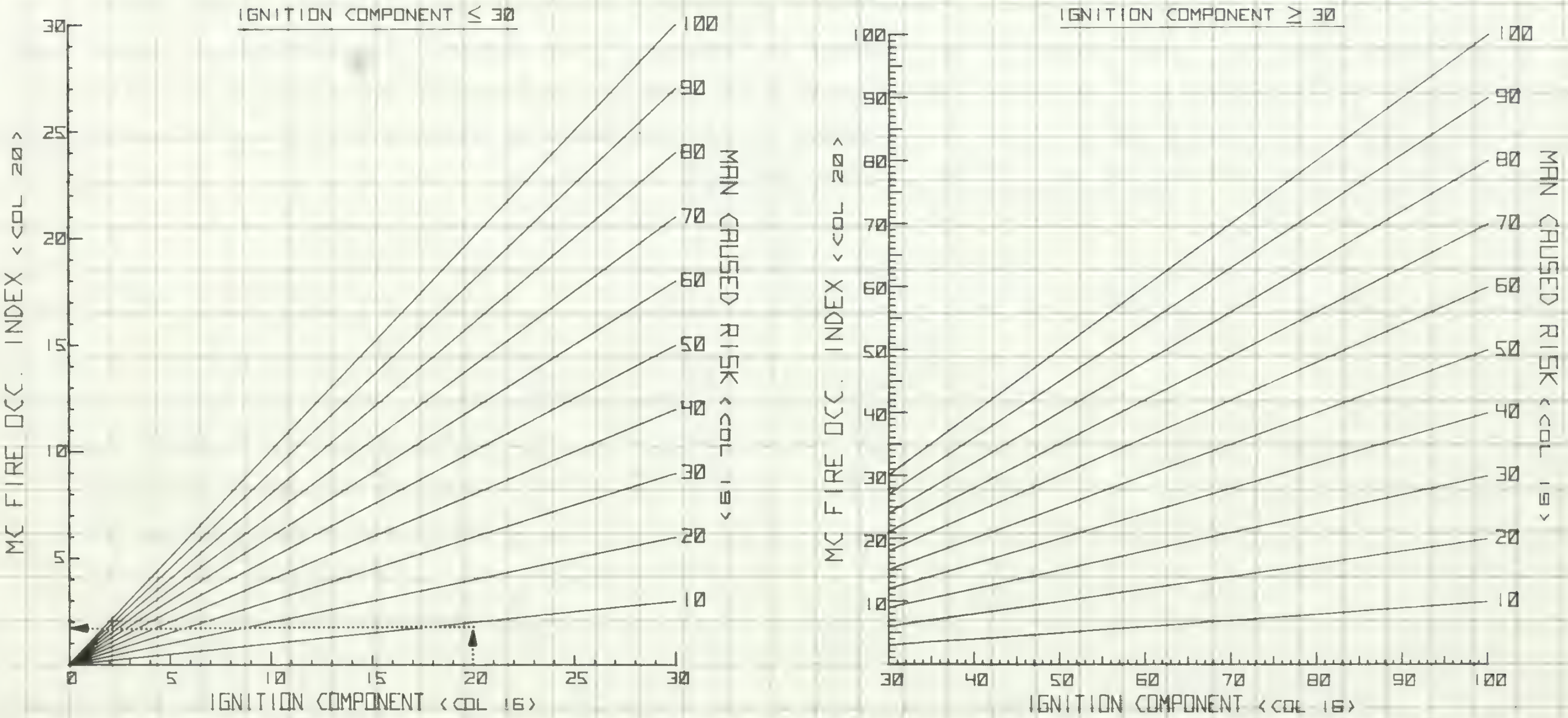
PARTIAL RISK

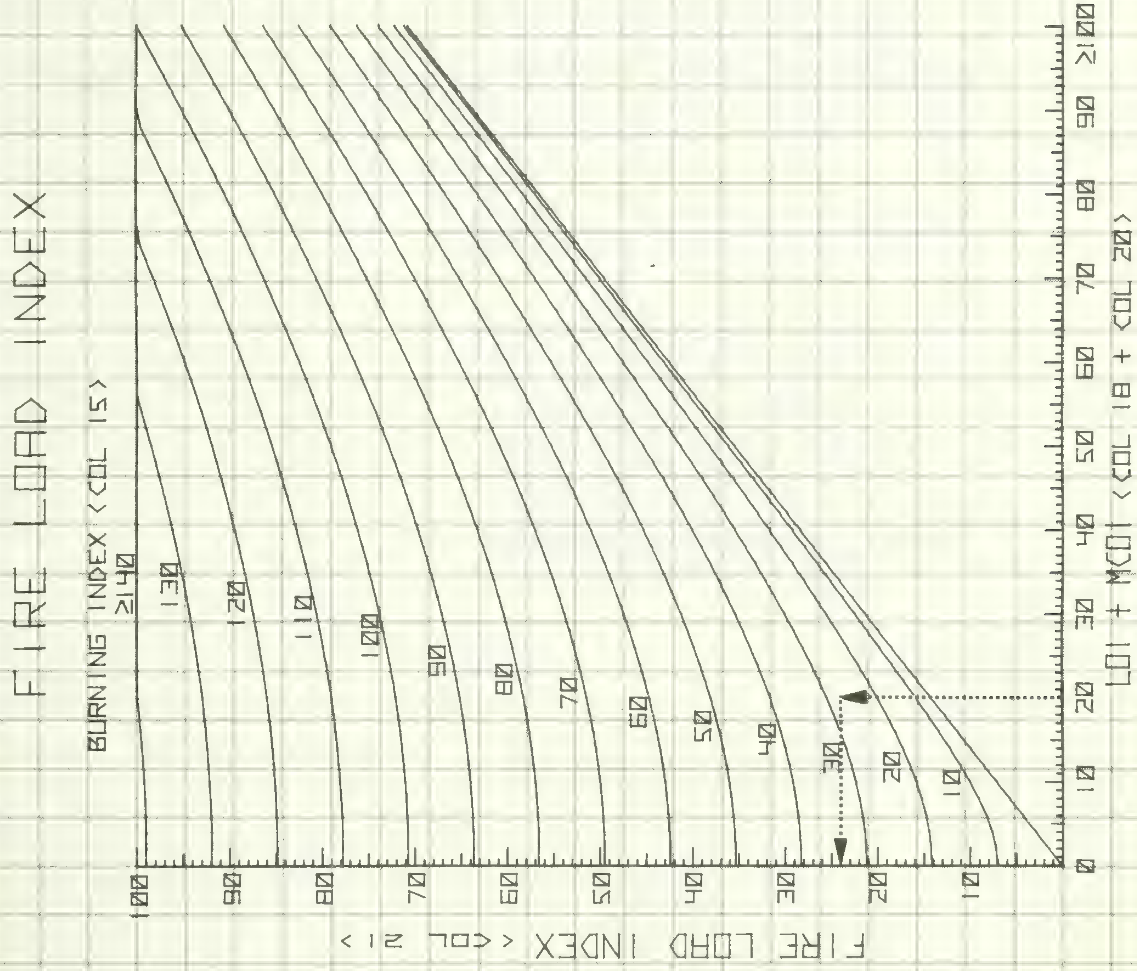


MAN-CAUSED RISK



MAN-CAUSED FIRE OCCURRENCE INDEX




FIRE LOAD INDEX
BURNING INDEX <COL 15>
≥140
130
120
110
100
90
80
70
60
50
40
30
20
10
FIRE LOAD INDEX <COL 21>
0
10
20
30
40
50
60
70
80
90
100
LOI + MCOI <COL 18 + COL 20>
0
10
20
30
40
50
60
70
80
90
≥100

10 DAY FIRE DANGER AND FIRE WEATHER RECORD	Agency FOREST SERVICE	Unit LIBBY DISTRICT	Station Name LIBBY	Station Number 240107

Station Elevation 2070	Fuel Model G ~~Annual or~~ Perennial P	Slope Class 3	Climate Class 3	Basic Obs Time (LST) 1400	Period of Record (Month,Day,Year) From 7/1/75	To 7/10/75

Observer

Checked By

Day of Month	State of Weather	Temperature: Dry Bulb	Temperature: Wet Bulb	Relative Humidity	Observed Fuel Sticks	10-Hr TL Fuel Moisture	1-Hr TL Fuel Moisture	Herb. Veg. Condition	Fine Fuel Moisture	Wind: Direction	Wind: Speed	Burning Index: Spread Component	Burning Index: Energy Release Component	Burning Index	Ignition Component	Occurrence Indexes: Lightning Risk	Occurrence Indexes: Lightning Occurrence Index	Occurrence Indexes: Man-caused Risk	Occurrence Indexes: Man-caused Occurrence Index	Fire Load Index	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
1	1	79		39	10	13	7		13		2	4	33	28	20	11	18	10	2	24	1/2" FM STICKS
2	2	81		32	7	10	6		12		2	4	36	30	22	0	4	19	4	22	ARE 3 MOS. OLD
3	3	69		34	8	11	7		13		2	4	36	30	19	0	0	15	3	21	
4	6	55		94	21	26	30+	98	30+		1	0	0	0	0	0	0	16	0	0	
5	3	61		69	28	33	16		19		1	3	20	20	3	0	0	20	1	14	
6	3	64		53	19	23	12		17		1	3	25	22	7	0	0	13	1	15	
7	1	72		40	11	14	8		15		4	4	30	28	17	0	0	15	2	20	
8	0	78		41	9	12	7		15		2	3	26	23	18	43	11	12	2	24	RECALCULATE 1000-HR
9	6	52		100	21	26	30+	98	30+		2	0	0	0	0	11	3	23	0	0	
0	3	57		67	26	31	16		19		3	3	16	18	3	11	2	25	1	13	
31																					

Daily (24 Hour) Data

Day of Month	Temperature: Maximum	Temperature: Minimum	Relative Humidities: Maximum	Relative Humidities: Minimum	Relative Humidities: Average	Precipitation: Kind	Precipitation: Began	Precipitation: Ended	Precipitation: Duration	Precipitation: Amount	Lightning: Began	Lightning: Ended	Lightning: Activity Level	100-Hr TL Fuel Moisture	1000-Hr TL Fuel Moisture: Today's 1000-Hr Bndry Value	1000-Hr TL Fuel Moisture: Average 7 Day Bndry Value	1000-Hr TL Fuel Moisture: Change 1000-Hr Fuel Moisture	1000-Hr TL Fuel Moisture: 1000-Hr TL Fuel Moisture	Living Fuel Moistures: Woody Fuel Moisture	Living Fuel Moistures: X1000 Moisture Value	Living Fuel Moistures: Herb Fuel Moisture	A	B	C	D
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	A	B	C	D
1	79	44	99	39	69				0				2	16	14	17	+1	15	110	14	100				
2	82	40	90	22	56				0				1	14	11	-	-	15	110	14	100				
3	84	44	99	20	60				0				1	13	12	-	-	15	110	14	100				
4	69	48	99	30	65	5	0500	1300	8	.16			1	16	41	-	-	15	110	14	100				
5	61	45	99	69	84	5	0200	1200	10	.32			1	20	54	-	-	15	110	14	100				
6	66	46	99	52	76	5	1600	1800	2	.05			1	19	22	-	-	15	110	14	100				
7	72	47	99	40	70	6	0800	0900	1	.04			1	18	17	-	-	15	110	14	100				
8	78	45	99	40	70				0				4	17	14	24	+3	18	140	16	110				
9	85	52	99	32	66	6	1300	1800	5	.29			2	18	29	-	-	18	140	16	110				
0	76	42	99	67	83	6	1600	1800	2	.12			2	19	24	-	-	18	140	16	110				
31																									

MAN-CAUSED RISK COMPUTATION FORM

Unit LIBBY DISTRICT Date 7/3/75

MCR scaling factor .18 Day of week SUNDAY

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1. EQUIPMENT USE	4	NORMAL	1
2. CAMPFIRES	27	HIGH	13
3. DEBRIS BURNING	19	NORMAL	5
4. ALL OTHER	8	NORMAL	2
5.			

Total - Unnormalized MC RISK - - - - - - - - - - - - - - 21

MCR (E-2) - 15

Unit LIBBY DISTRICT Date 7/4/75

MCR scaling factor .18 Day of week MONDAY

Risk source	Risk source ratio	Daily activity level	Partial risk (E-1)
1. EQUIPMENT USE	26	LOW	3
2. CAMPFIRES	12	EXTREME	12
3. DEBRIS BURNING	18	NORMAL	5
4. ALL OTHER	8	NORMAL	2
5.			

Total - Unnormalized MC RISK - - - - - - - - - - - - - - 22

MCR (E-2) - 16

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APPENDIX A

ESTIMATING THE MAXIMUM AND MINIMUM RELATIVE HUMIDITIES

If your station is equipped with a properly adjusted and maintained hygrothermograph, the maximum and minimum RH for the 24-hour period ending at your basic observation time is already available. However, if only wet-dry bulb and maximum-miniumum temperatures are available, the following procedure must be used to estimate the 24-hour maximum and minimum relative humidities:

1. 24-Hour Maximum Relative Humidity

   a. If frost or dew was observed on vegetation (not on glass or metal) or if precipitation or fog was observed during the preceding 24 hours, assume the maximum RH to be 100 percent.

   b. If no frost, dew, precipitation, or fog was observed, the maximum RH must be estimated. First, compute the dew point at today's basic observation time (record in column A). Read the estimated 24-hour maximum RH from the accompanying table (page 44) at the intersection of the row indexed by the 24-hour minimum temperature and the column indexed by the dew point. *The value recorded should not be less than either yesterday's or today's basic observation time relative humidities.*

2. 24-Hour Minimum Relative Humidity

   From the accompanying table (page 44), read the 24-hour minimum RH at the intersection of the row indexed by the 24-hour maximum temperature and the column indexed by today's dew point. *The computed minimum RH should not be greater than either yesterday's or today's basic observation time relative humidity.*

24-HOUR MAXIMUM (MINIMUM) RELATIVE HUMIDITY (PERCENT)
Col. 25 (Col. 26)

24-HOUR MINIMUM (MAXIMUM) TEMPERATURE F COL 24 (COL 23)	DEW POINT (°F) Col. 4																									
	-15→-12	-11→-8	-7→-4	-3→0	1→4	5→8	9→12	13→16	17→20	21→24	25→28	29→32	33→36	37→40	41→44	45→48	49→52	53→56	57→60	61→64	65→68	69→72	73→76	77→80	81→84	85→88
1→4	46	56	68	83	100																					
5→8	38	47	57	69	83	100																				
9→12	32	39	48	58	69	84	100																			
13→16	27	33	40	48	58	70	84	100																		
17→20	23	28	33	41	49	59	70	84	100																	
21→24	19	23	28	34	41	50	59	71	84	100																
25→28	16	20	24	29	35	42	50	60	71	85	100															
29→32	14	17	20	25	30	36	43	51	61	72	85	100														
33→36	12	14	17	21	25	30	36	43	52	61	72	85	100													
37→40	10	12	15	18	22	26	31	37	44	52	62	73	85	100												
41→44	9	10	13	15	18	22	27	32	38	45	53	62	73	86	100											
45→48	7	9	11	13	16	19	23	27	32	38	45	53	63	73	86	100										
49→52	6	8	9	11	14	16	20	23	28	33	39	46	54	63	74	86	100									
53→56	5	6	8	10	12	14	17	20	24	28	34	40	47	55	64	74	86	100								
57→60	5	6	7	8	10	12	15	17	21	25	29	34	40	47	55	64	75	87	100							
61→64	4	5	6	7	9	11	13	15	19	21	25	30	35	41	48	56	65	75	87	100						
65→68	4	4	5	6	8	9	11	13	16	19	22	26	30	36	42	48	56	65	75	87	100					
69→72	3	4	5	6	7	8	10	11	14	16	19	23	26	31	36	42	49	57	66	76	87	100				
73→76	3	3	4	5	6	7	8	10	12	14	17	20	23	27	32	37	43	50	57	66	76	87	100			
77→80	2	3	4	4	5	6	7	9	10	12	15	17	20	24	28	32	38	44	50	58	67	77	88	100		
81→84	2	3	3	4	5	5	6	8	9	11	13	15	18	21	24	28	33	38	44	51	59	67	77	88	100	
85→88	2	2	3	3	4	5	5	7	8	10	11	13	16	18	21	25	29	34	39	45	51	60	68	77	88	100
89→92	2	2	2	3	4	4	5	6	7	8	10	12	14	16	19	22	26	30	34	39	45	52	60	68	78	88
93→96	1	2	2	3	3	4	4	5	6	7	9	10	12	14	17	19	23	26	30	35	40	46	53	60	68	78
97→100	1	2	2	2	3	3	4	5	6	7	8	9	11	13	15	17	20	23	27	31	35	41	47	53	61	69
101→104	1	1	2	2	2	3	3	4	5	6	7	8	10	11	13	15	18	21	24	27	31	36	41	47	54	61
105→108	1	1	1	2	2	3	3	4	4	5	6	7	9	10	12	14	16	18	21	24	28	32	37	42	48	54
109→112	1	1	1	2	2	2	3	3	4	5	5	6	8	9	10	12	14	16	19	22	25	29	33	37	43	48
113→116	1	1	1	1	2	2	2	3	3	4	5	6	7	8	9	11	13	14	17	19	22	25	29	33	38	43
117→120	1	1	1	1	2	2	2	3	3	4	4	5	6	7	8	10	11	13	15	17	20	23	26	30	34	39

Example

The 24-hour maximum and minimum temperatures, 87° F. and 61° F; dry bulb and wet-bulb temperatures at Basic Observation Time, 83° F. and 65° F. Using the 23-inch psychrometric tables, the RH and dewpoint at Basic Observation Time are 41 percent and 57° F. From the accompanying table the 24-hour maximum RH is 87 percent; the 24-hour minimum RH is 39 percent.

APPENDIX B

ESTIMATING THE 10-HOUR TIMELAG FUEL MOISTURE

These nomograms (pages 46, 47) can be used (1) for predicting the next day's 10-h TL FM, and (2) for estimating the current day's 10-h TL FM if fuel moisture sticks are not used.

A specific example will illustrate the procedure:

EXAMPLE:

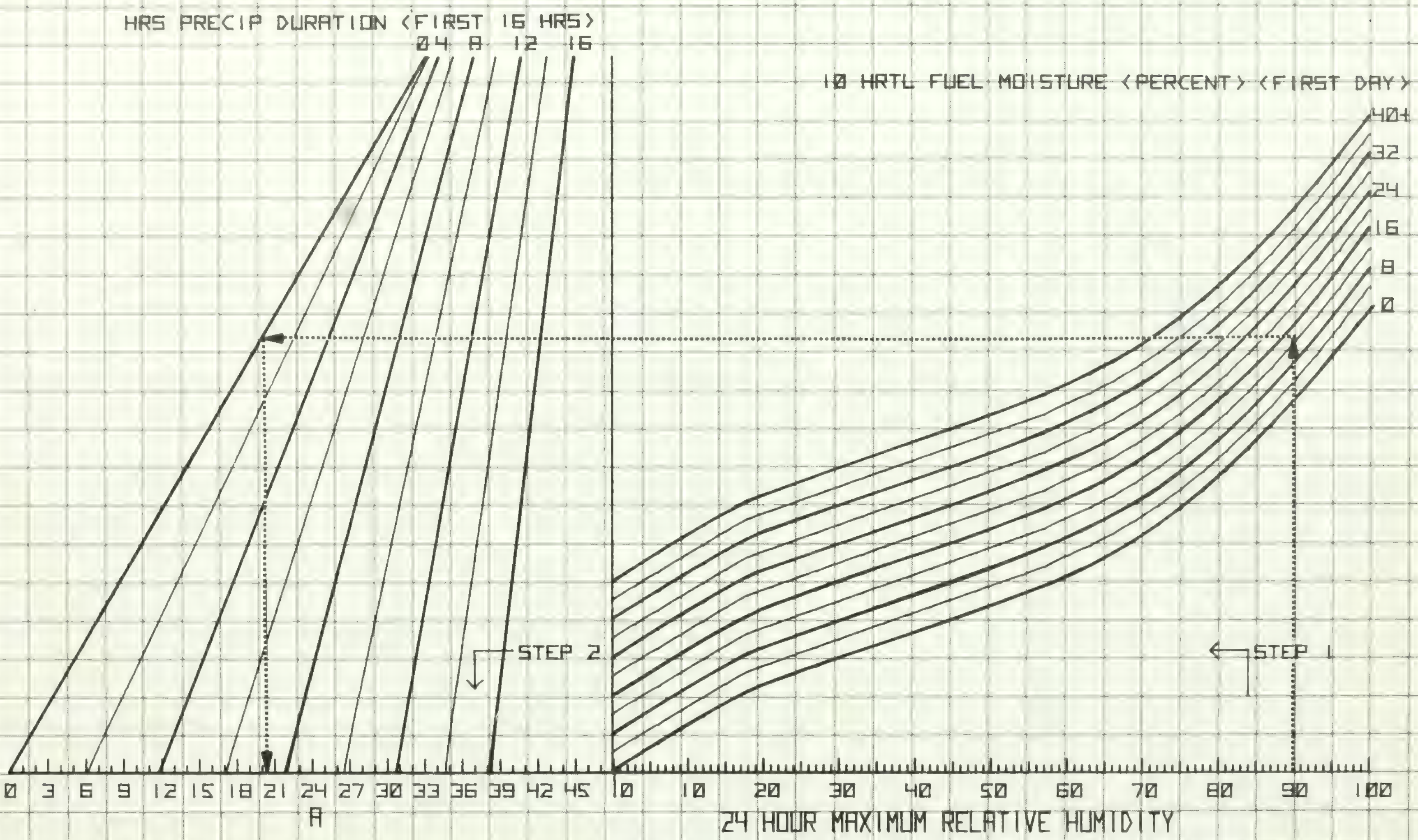
What is the predicted 10-h TL FM at basic observation time tomorrow?

85 percent -- 24-hour maximum relative humidity.
8 percent -- 10-h TL FM at basic observation time today.
2 hours -- Forecasted precipitation duration for the 16-hour period starting at basic observation time today.
15 percent -- Forecasted relative humidity at basic observation time tomorrow.
0 hours -- Forecasted precipitation duration for the 8 hours preceding tomorrow's basic observation time.

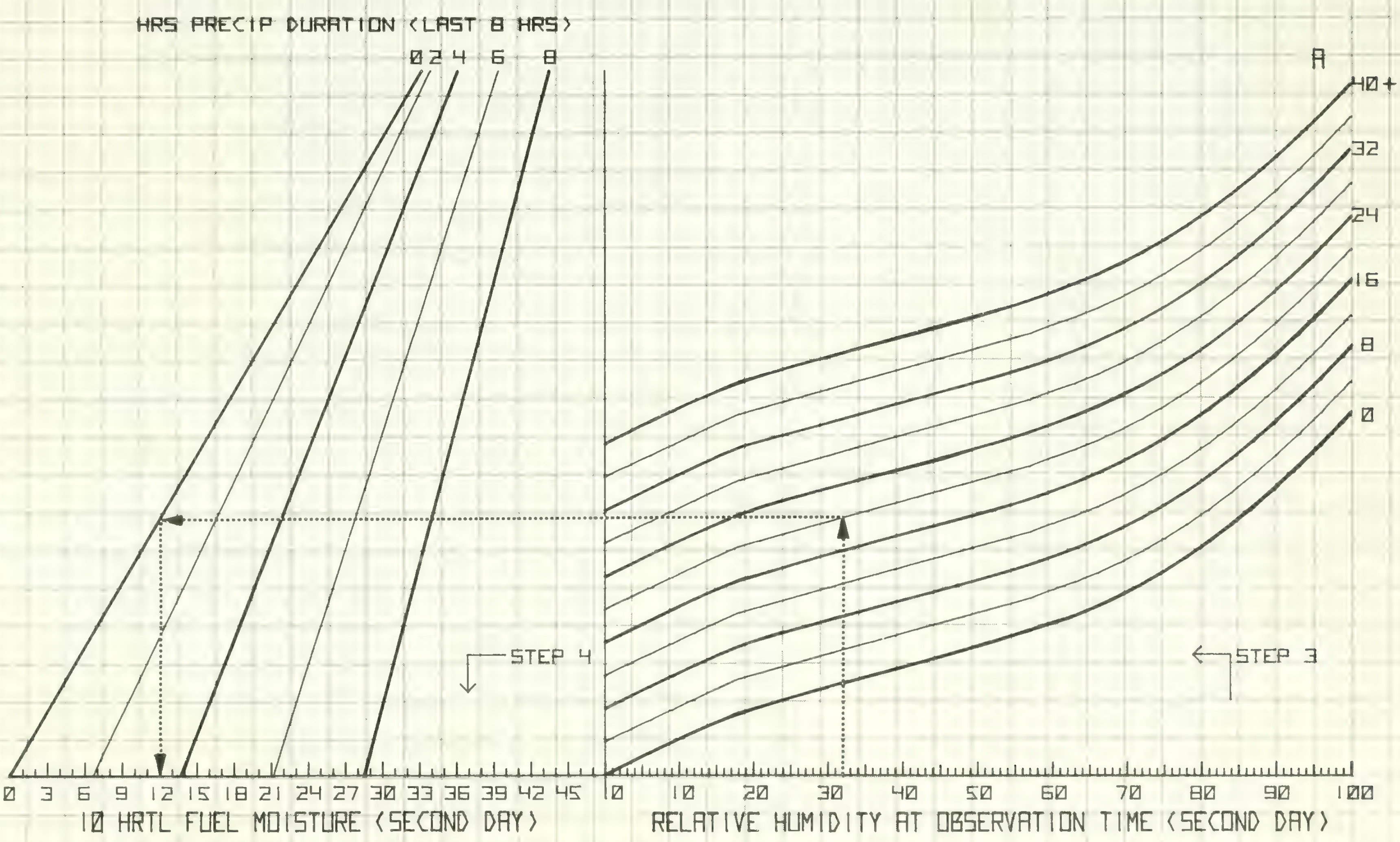
The arrows trace the procedure through nomogram. Notice that "A," the result from step 2, is used to select from the family of curves in step 3; it is *not* entered on the x-axis.

If a satisfactory procedure for predicting the 10-h TL FM is currently available in your area or region, it is not necessary to use the procedure presented here. Simpler, empirical techniques, such as the one developed by Cramer (1961), may prove more accurate for local use. The NFDRS method is meant for general application; hence its complexity.

10 HOUR TIMELAG FUEL MOISTURE



10 HOUR TIMELAG FUEL MOISTURE



APPENDIX C

PUNCHCARD FORMAT FOR USE WITH THE 10-DAY FIRE DANGER AND FIRE WEATHER RECORD

This card format was designed for use with the revised 10-Day Fire Danger and Fire Weather Record proposed for use with the 1978 NFDRS. It was assumed that the 10-day record will be used as the source document.

The format published in RM-84 (Deeming and others 1972) should continue to be used with the WS Form D-9A. For identification purposes, the RM-84 format should be referenced as the "1972 format," and the following as the "1978 format."

For punched data to be included in the National Fire Weather Library (Furman and Brink 1975), send cards to:

NFDR Liaison
Boise Interagency Fire Center
3905 Vista Avenue
Boise, Idaho 83705

Notice that only observed data are punched. The computer will recalculate fuel moistures, components, and indexes when needed.

If, and ONLY if, the woody fuel moisture or the dead fuel moisture contents (1-, 10-, and 100-h TL) are observed are these values to be punched. For instance, if the 10-h TL FM is determined from the fuel sticks, it should be punched; if it is estimated, leave card columns 20, 21, and 22 blank.

PUNCHCARD FORMAT 10-DAY FIRE DANGER AND FIRE WEATHER RECORD

Field No.[1]	Heading	Columns			Remarks[2]
		From	To	No. of	
	Station number	1	6	6	Heading
	Year	7	8	2	Heading
	Month	9	10	2	Heading
1	Day	11	12	2	
2	State of weather		13	1	
3	Dry bulb temperature	14	16	3	If negative, put -- in column 14.
4	Humidity variable[3]	17	19	3	If negative, put -- in column 17 (see Humidity Variable Identifier.)
7	10-h TL FM[4]	20	22	3	Analog values only.
8	1-h TL FM[4]	23	25	3	Analog or stick values only.
9	Herb. Veg. Condition	26	27	2	Enter G, C, or F for greenup, curing, or freezing, respectively. Enter on the day of occurrence only.
11	Wind direction		28	1	8 pt. compass.
12	Windspeed	29	31	3	
19	Man-caused risk	32	34	3	
23	24-hour maximum temperature	35	37	3	If negative, put -- in column 35.
24	24-hour minimum temperature	38	40	3	If negative, put -- in column 38.
25	24-hour maximum RH	41	43	3	
26	24-hour minimum RH	44	46	3	
28	Precipitation kind		47	1	
31	Precipitation duration	48	49	2	During previous 24 hours; nearest whole hour.
32	Precipitation amount	50	53	4	Two decimal places; for trace, enter T.
35	Lightning activity level	54	56	3	
36	100-h TL FM[4]	57	59	3	Analog values only.
41	Woody fuel moisture[4]	60	62	3	
	Humidity variable identifier		63	1	Enter a 1 for wet bulb; 2 for relative humidity; or a 3 for dew point.
	Format identifier	79	80	2	Enter 78.

---

[1] From the 10-Day Fire and Weather Record.

[2] If no data, leave field blank.

[3] Wet bulb, relative humidity, or dew point.

[4] Entered only when data from fuel moisture sticks or other kinds of analogs are available; otherwise leave blank.

NFDR LIAISON
Boise Interagency Fire Center
3905 Vista Avenue
Boise, Idaho 83705

Please send the following NFDRS nomograms to:

____

____

____

Type 1 and 2 nomograms

____ Sets

____ A
____ B
____ C
____ D
____ E

____ F
____ G
____ H
____ I
____ J

____ K
____ L
____ N
____ O
____ P

____ Q
____ R
____ S
____ T
____ U

Nomogram Order Blank

Order one set of type 1 and 2 nomograms for each fire weather station and one set of type 3 nomograms for each fuel model to be used at each fire weather station. Enter number desired in the appropriate blanks.

Burgan, Robert E., Jack D. Cohen, and John E. Deeming.
1977. Manually calculating fire-danger ratings--1978 National Fire-Danger Rating System. USDA For. Serv. Gen. Tech. Rep. INT-40, 51 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

This publication contains instructions for manually calculating the indexes and components of the 1978 National Fire-Danger Rating System (NFDRS). The procedures are explained with worked examples. Working sets of nomograms for the 20 NFDRS fuel models are not included. However, an order form for obtaining the needed nomograms is provided.

USDA Forest Service General Technical Report INT-39, The National Fire-Danger Rating System--1978 by John E. Deeming, Robert E. Burgan, and Jack D. Cohen, a companion publication, covers the NFDRS background, applications, and general principles of the system.

KEYWORDS: fire-danger rating, danger rating meters, burning index, fuel moisture content, lightning, man-caused fires, fire weather.

Burgan, Robert E., Jack D. Cohen, and John E. Deeming.
1977. Manually calculating fire-danger ratings--1978 National Fire-Danger Rating System. USDA For. Serv. Gen. Tech. Rep. INT-40, 51 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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KEYWORDS: fire-danger rating, danger rating meters, burning index, fuel moisture content, lightning, man-caused fires, fire weather.

U. S. [illegible]

NATIONAL
FIRE-DANGER
RATING SYSTEM

Evaluation of Liquid Ammonium Polyphosphate Fire Retardants

C. W. George,
A. D. Blakely,
G. M. Johnson,
D. G. Simmerman,
C. W. Johnson

USDA Forest Service
General Technical Report INT-41
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE

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    Southwestern Region
    San Dimas Equipment Development Center
    Aviation and Fire Management Staff, Chief's Office

USDA Forest Service
General Technical Report INT-41
October 1977

EVALUATION OF LIQUID AMMONIUM POLYPHOSPHATE FIRE RETARDANTS

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CONTENTS

Page

INTRODUCTION. 1

DEVELOPMENT HISTORY 2

EVALUATION OF FIRE-TROL 931 APP FORMULATIONS . . 8

- Storage (3.1.1.) 8
- Specific Weight (3.1.2.) 10
- Viscosity (3.1.3.) 12
- Corrosion (3.1.4.) 16
- pH Values (3.1.5.) 20
- Abrasion and Erosion (3.1.6.) 21
- Combustion Retarding Effectiveness (3.1.7.) 22
- Color (3.1.8.) 24
- Health and Safety (3.1.9.) 25
- Mixing (3.1.10.) 26
- Salt Content (3.1.11.) 26
- Separation (3.1.12.) 27
- Spoilage (3.1.13.) 31
- Pumpability (3.1.14.) 31
- Air Drop Characteristics (3.1.15.) 32

DISCUSSION. 35

RECOMMENDATIONS 39

PUBLICATIONS CITED. 39

APPENDIX 41

Use of trade or firm names is for reader information only, and does not constitute endorsement by the U.S. Department of Agriculture of any commercial product or service.

ABSTRACT

This report summarizes the development, history, and operational use of liquid ammonium phosphate and polyphosphate fire retardants since their first use in the early 1960's. Several liquid ammonium polyphosphates were evaluated as long-term forest fire retardants in accordance with Forest Service specifications and test procedures. Retardants were laboratory tested to quantify various physical properties, corrosion potential, and combustion retarding ability, and were drop-tested from aircraft. Performance of products is discussed and recommendations are made relative to meeting current Forest Service specifications and satisfying current and future operational needs.

INTRODUCTION

Since chemicals were first used to combat wildfires many different formulations have been tried. Thickeners were one of the first important additives combined with water to increase its effectiveness. The thickened water adhered to fuels in heavier layers to dissipate more heat than unthickened water. Eventually, chemicals were included in the thickened water to alter the combustion process of the fuel by causing lower production of flammable pyrolysis products. When spoilage and corrosion of some formulations occurred, chemical inhibitors were added. The most effective fire retardant chemical additives were ammonium phosphate (DAP), polyphosphate (APP), pyrophosphate (Pyro), and sulfates (AS). DAP and AS are mixed with water as dry powder-type retardants and APP and Pyro as liquid-type retardants.

As numerous products containing several different chemicals were made available, it became necessary to screen and test formulations before they were accepted by the Federal Government and put on the market for general use. Procedures were written and incorporated into Forest Service specifications to provide a basis for testing, qualifying, GSA purchasing, and retesting products as necessary. All new retardant formulations submitted for USDA Forest Service use now must be tested against requirements in current specifications for dry retardants or for liquid retardants. Final performance evaluation and approval for the Forest Service are given by the Washington Office Division of Fire Management. Many States and other Federal agencies often comply with the evaluations and approval decisions that are based on the Forest Service Specifications.

This report discusses the development history, operational use, and related performance requirements of APP-based forest fire retardants and details their performance when tested and evaluated according to USDA Forest Service Specification 5100-00302a for liquid fire retardants. Most of the formulations discussed contain 10-34-0 ammonium polyphosphate and are referred to as APP solutions. In everyday language, several of these are referred to as liquid concentrates or LC.

Ammonium polyphosphates differ considerably in their composition, but usually contain 20-30 percent polyphosphate (P_3O_8 or greater), 30-50 percent pyrophosphate (P_2O_7), and 20-50 percent orthophosphate (PO_4). Numerous laboratory tests have shown that the effectiveness of ammonium phosphate solutions is related to the amount of active phosphate that is available to alter pyrolysis and combustion reactions. Impurities such as calcium, magnesium, and iron in these solutions can chemically tie up available phosphate and reduce the effectiveness. Most dry ammonium phosphate salts (DAP) and "white acid"- or electric furnace-produced liquid phosphates (APP or Pyro) usually contain few impurities and thus do not significantly reduce the solution effectiveness. "Green acid"-produced dry salts or liquids (currently used APP or LC) however, can contain many impurities and reduce the effectiveness of the solutions by 10 percent or more (on a P_2O_5 equivalence basis). Thus, total phosphate concentration does not necessarily quantitatively relate to "retardant effectiveness." This is shown by data included in this report as well as that on file at the Northern Forest Fire Laboratory, Missoula, Montana.

DEVELOPMENT HISTORY

Several different dry-type ammonium phosphates were evaluated as forest fire retardants both individually and in complex formulations during the late 1960's. Included were several ammonium polyphosphates such as MAPP (monoammonium polyphosphate), 15-60-0, and several long-chain, water-insoluble ammonium polyphosphates that are often used in fire retardant paints. Liquid-type ammonium pyrophosphate (Pyro or 11-37-0) was evaluated and used operationally in the Southeast (Johansen and Crow 1965), but the liquids were not formulated with coloring, corrosion inhibitors, thickening agents, or other additives. This liquid product was not used in the Western States until 1970, apparently because of undesirable physical properties and not because of the effectiveness of the basic chemicals.

During tests in the late 1950's in California (Davis 1959; Davis and others 1961, 1962, 1963; Phillips and Miller 1961), unthickened and thickened ammonium phosphate was dropped from aircraft and applied by ground tankers onto chaparral-type fuel. Although the tests were quite subjective, it was concluded that thickening agents were necessary to improve the drop characteristics and/or to increase retention on fuels, especially for fires spreading through aerial fuels during windy conditions and/or in steep terrain where high aircraft drops were necessary. Viscous products such as Bentonite, Borate, Algin-Gel, Gelgard, Algin-DAP, Pectin-DAP, CMC-DAP, and eventually Phos-Chek and Fire-Trol 100 were developed to improve the drop characteristics of water or retardant solutions.

Meanwhile, in the Southeast States, fire control personnel were successfully dropping Pyro (with no additives) from air tankers with few, if any, apparent delivery problems. This successful use created numerous Pyro advocates who could not understand the lack of interest by western fire control personnel in using this product. Discussions began as to whether coloring, corrosion inhibitors, or other additives were really necessary and led to a controversy over the use of such chemicals.

The proponents of Pyro suggested that the Southeast's fire retardant needs and use levels were comparable to those of the Western States and therefore proposed that the same materials could be used in all regions. However, the amount of use, general practices, type of fuel, type of fire, and topography in the areas where Pyro was being used were considerably different from those in the Western States. For example, the amount of use: for the years 1962 through 1969, the Southern Region of the Forest Service dropped 958,000 gallons of liquid concentrate (Pyro) for an average annual use of about 120,000 gallons (the peak year was 1963 when 288,000 gallons were used). During the same period, the Western Regions (Northern, Rocky Mountain, Southwestern, Intermountain, California, and Pacific Northwest) of the Forest Service dropped 38,945,000 gallons for an average annual use of 4,868,125 gallons. In addition to the retardant used by the Forest Service in the West, the average annual use for the California Division of Forestry and the Bureau of Land Management for this period was 2,863,000 and 846,000 gallons, respectively. Thus, during this 8-year period, the use of Pyro averaged less than 2.5 percent of the retardant used annually by the Forest Service or approximately 1.4 percent of the total retardant use in the West.[1]

---

[1] Data collected, summarized, and reported by individual Regions and agencies. Summary data acquired from conversations with agency personnel is on file at the Northern Forest Fire Laboratory, Missoula, Montana.

Another example is general use practices. Air tankers normally do not sit loaded with retardant in the Southeast. However, water is kept in the tanks, requiring that only the Pyro be added when a fire call is received. Thus, exposure of the aircraft and mixing system to retardant is minimized and retardant-caused corrosion should be minimal. This practice is not encountered in the West. A recent survey (August 2-7, 1974) of 47 western retardant bases having 73 aircraft available disclosed that 59 percent of the air tankers were required to sit loaded in readiness during the fire season, while only 5 percent of the air tankers never sit loaded. The remaining air tankers occasionally sit loaded (see data in DISCUSSION section). From this discussion, one might conclude that different performance requirements or specifications might be applicable for different parts of the country, depending on the type of fire problem, conditions of use, and the operational methods or practices.

In the Pacific Northwest Region, severe corrosion occurred on mixing, pumping, and storage facilities over an 8- to 10-year period, requiring extensive repair, refurbishing, and replacement of some equipment to maintain operational readiness. (Data on file at the Northern Forest Fire Laboratory, Missoula, Montana.) Retardant-caused corrosion occurring at these bases was primarily to mild steel although other alloys were often affected. The Pacific Northwest Region bases had used Fire-Trol 100 exclusively since the early 1960's. The ammonium sulfate based Fire-Trol 100 is adequately inhibited for aluminum (<1 mil/yr on Al-2024-T3) but exhibits significant corrosion to mild steel, brass, copper, and some other alloys.

Before making extensive repairs, Fire Management personnel from the Pacific Northwest Region decided to investigate the possibility of changing retardant types. Prior to the selection of a different fire retardant, fire control and equipment specialists traveled throughout the Southeast to look at the facilities and determine the needs for storing, mixing, and handling Pyro. The simplicity of the liquid system and apparent lower cost of manpower, hardware, and retardant were primary considerations which resulted in operational trials of a liquid retardant system in the Pacific Northwest Region at Lakeview, Oregon, and Wenatchee, Washington (Wood 1970). During 1969, 117,000 gallons of APP were dropped on 28 fires from aircraft operating out of these bases. In general, fire control personnel were favorably impressed with the effectiveness of APP in the Northwest. It was determined, however, that coloring in the formulation was necessary (it was first thought that a flag-type marking system would be adequate). When the costs of coloring, clay to hold the color in suspension, corrosion inhibitors, and transportation were included, the apparent cost advantages were substantially reduced. (The cost of Pyro in the South was considerably below costs for Pyro or other ammonium polyphosphate fertilizers (such as 10-34-0) encountered in the West. The cheaper cost for Pyro was primarily due to local marketing (Muscle Shoals, Alabama) by TVA (Tennessee Valley Authority), a Federal agency. In addition, the primary source of 10-34-0 in the Northwest was from Allied Chemical Company, which actually manufactures the product in Giesmar, Louisiana, and transports the material by ocean tankers to west coast outlets in Pasco, Washington, Portland, Oregon, and Wilmington and Richmond, California.)

It is important to note that direct effectiveness comparisons had been made with Fire-Trol 100 only. It is understandable that in experiences gained during operational use, the unthickened APP (Fire-Trol 931) was found to be equal or superior in effectiveness to the Fire-Trol 100 slurry. Considerable research (both laboratory and field tests) has been conducted to quantify the relative effectiveness of ammonium sulfate and ammonium phosphate compounds (George and Susott 1971; George and Blakely 1972; Johansen 1959). On an equal concentration basis, ammonium sulfate (as contained in Fire-Trol 100) is less effective in reducing the rate of spread and fire intensity than are ammonium phosphate compounds (George and Blakely 1972). This is because ammonium sulfate decomposes at a lower temperature (less than flame temperatures) than does ammonium phosphate and is thus not available to alter fuel pyrolysis and combustion reactions. In addition, drop tests (George and Blakely 1973; George 1975) indicate little difference in the retardant breakup and drop characteristics between unthickened retardants (such as water and Fire-Trol 931) and the clay-thickened Fire-Trol 100. Although this phenomenon has been observed in numerous drop tests, only recently have we learned about the mechanisms involved.

Shock Hydrodynamics, under Forest Service contract (Andersen and others 1974b, 1974c), investigated the effects of retardant rheological properties, and determined that aerial breakup was not a function of apparent viscosity, as previously thought. Breakup characteristics were related to the effective viscosity, which incorporates the effect of shear rate and retardant elasticity. Under shear rates encountered during primary breakup (10-1500 s^{-1}), it was found that the gum-thickened retardants had a significantly higher effective viscosity than clay-thickened Fire-Trol 100, unthickened Fire-Trol 931, or water--which all had similar effective viscosities (table 1).

Although the Northern Forest Fire Laboratory had previously conducted a number of investigations (retardant evaluation quarterly reports on file at the Northern Forest Fire Laboratory, Missoula, Montana) to determine the effectiveness of liquid ammonium phosphate and polyphosphate solutions, the first evaluation of a complete formulation was in 1968 when Collier Carbon and Chemical Company (a subsidiary of Union Oil Company of California) submitted a thickened liquid ammonium phosphate product. The system involved the metered addition of calcium chloride into a diluted 8-24-0 liquid ammonium phosphate fertilizer. The calcium chloride reacted to form a tricalcium phosphate complex in suspension, creating a thickened slurry. Laboratory tests conducted at the Northern Forest Fire Laboratory and actual operational use from a base at Chino, California, indicated the sensitivity of the final slurry suspension to calcium chloride concentration, to the pH of the 8-24-0, and to shear during mixing, made it impossible to control rheological properties of the slurry.

Table 1.--*Effective retardant viscosity during retardant breakup and application*[1]

Phase of drop	Shear rate	Effective viscosity (centipoise)			
		Phos-Chek XA[2]	Fire-Trol 100	Fire-Trol 931 (LC)	Water
Deformation	Low (1-4 s^{-1})	3,700	10,000	500	1
Liquid instability	Low to high (10-1500 s^{-1})	1,400	200	50	1
Surface erosion	Medium to high (700-1400 s^{-1})	900	45	7	<1
Fuel impaction[3]	Low ($\sim$1-4 s^{-1})	$\sim$3,700	$\sim$10,000	$\sim$500	$\sim$1

[1] Data from "Investigation of Retardant Rheological Properties," final report, Shock Hydrodynamics Division, Whittaker Corporation, North Hollywood, California, 1974.

[2] Phos-Chek XA contains a modified polysaccaride (guar gum) thickening agent and is representative of a "gum-thickened type" retardant.

[3] Not yet completely quantified--approximately equal to values given for effective viscosities during the deformation phase.

In early 1968, Allied Chemical Company submitted Arcadian Poly-N 10-34-0 ammonium polyphosphate for evaluation. Several limiting factors were encountered--notably corrosion, lack of coloring and thickening agents, and storability. Allied, in cooperation with the Northern Forest Fire Laboratory, began testing several promising corrosion inhibitors. During this time, Arizona Agrochemical Corporation (now Chemonics Industries) began discussion with Allied and arrived at an agreement by which Chemonics Industries would cooperate in a developmental program using Allied Arcadian Poly-N for fire retardant use.[2] In August 1968, Chemonics Industries submitted Fire-Trol 931-A, the first of a series of formulations containing APP (Arcadian Poly-N), corrosion inhibitors, coloring agents, and attapulgite clay to suspend the coloring agent in the concentrate. Other Fire-Trol formulations followed (Fire-Trol 931-B, 931-C, and 931-D) with similar composition except for the corrosion inhibitor or inhibitors. Fire-Trol 931-D was the formulation used operationally on a trial basis in the Pacific Northwest Region the following year (1969). (The composition of each Fire-Trol 931 formulation is given in appendix A.)

Because Fire-Trol 931-A through 931-D did not initially meet the current Forest Service performance standards for either corrosion or solution stability (separation or storability), emphasis in the development and evaluation was placed on these properties. The retardant corrosion requirements became quite controversial for both fire control and research and development personnel. Requirements and specifications developed previously for thickened fire retardants (Phos-Chek XA and Fire-Trol 100) contained a corrosion performance requirement of ≤1 mil/yr on aluminum 2024-T3 and a tendency toward pitting of less than 5 (dimensionless numerical rating obtained with Magna Corrater model 1180) in addition to no evidence of intergranular corrosion.[3]

Pyro and APP advocates argued that the corrosion requirements were too stringent and the operational use of Pyro with little apparent corrosion was evidence that stated corrosion problems and 1 mil/yr requirements were unrealistic. Numerous corrosion problems, however, had been documented[4] with mixing, handling, and storage equipment which was being used with retardants meeting the 1 mil/yr requirements (Fire-Trol 100 and Phos-Chek XA) (Davis and Phillips 1965). Because of this corrosion, R&D personnel took the position that since ≤ 1 mil/yr corrosion rate on Al-2024-T3 had been achieved with Phos-Chek XA and Fire-Trol 100, the same performance should be required for the APP formulations if that level of performance was practically and economically attainable. (The 1 mil/yr requirement on Al-2024-T3 can be attained since an APP formulation (10-34-0, coloring, and corrosion inhibitors) submitted by Stauffer Chemical Company has been evaluated and met the requirement. Although it appeared that the formulation would be approved, Stauffer withdrew it from evaluation prior to final approval.)

To resolve the controversy over corrosion requirements, a contract was let by the Forest Service to Ocean City Research Corporation (OCRC) in June 1973. Ocean City Research Corporation, which specializes in corrosion research and consultation, conducted field surveys of aircraft and retardant plant facilities, performed laboratory corrosion tests on present retardant formulations and on alloys determined critical during the field survey, and investigated new inhibitors and protective systems (Gehring 1974). The program was designed to quantify the extent of actual corrosion occurring in the field, correlate the results with laboratory results, and make recommendations for performance requirements, evaluation methods, procedures for minimizing damage, and alloys to avoid using. The initial program has been completed and a summary of conclusions and recommendations is given in Appendix B. Additional research about the problem is being conducted by both the Forest Service and OCRC under a contract amendment.[5]

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[2] Private communication with Allied Chemical Company and Chemonics Industries personnel.

[3] USDA Forest Service Interim Specifications, 1969-1970.

[4] Retardant evaluation quarterly status reports on file at the San Dimas Equipment Development Center, San Dimas, California.

During this period, Chemonics Industries submitted numerous liquid phosphate formulations containing different corrosion inhibitors and types (manufacturers or manufacturing process) of ammonium polyphosphate in an attempt to achieve a corrosion rate of $\leq$1 mil/yr on Al-2024-T3 as determined by the Magna Corrater and as outlined in USDA Forest Service Specifications 5100-00301 and 5100-00302a. (Retardants for ground application (type G) also required a corrosion rate of $\leq$3 mil/yr on Al-2024-T3, mild steel AISI C-1010, prime western (ASTM) zinc, and free-cutting brass (Fed. Spec. QQ-B-626 composition 22).)

Fire-Trol 931-D was first used operationally in the Pacific Northwest Region under interim approval by Washington Office Fire Management and purchased under Forest Service Specification 5100-00302a. Exceptions allowed a uniform corrosion rate of 5 mil/yr (0.005 in) on Al-2024-T3 and a separation of 12 percent by volume (specification requirements were 1 mil/yr and 5 percent separation by volume).

The formulation (Fire-Trol 931-D) contained sodium dichromate corrosion inhibitor and Allied Poly-N 10-34-0 APP. In the summer of 1972, the manager of The Dalles, Oregon, city water treatment and watershed became concerned about the Pacific Northwest Region's use of retardant containing "toxic elements as a part of their chemistry," referring to hexavalent chromium. (Correspondence on file at the Northern Forest Fire Laboratory, Missoula, Montana.) After much deliberation, the Fire-Trol 931-APP formulation was altered; the sodium dichromate was replaced by a corrosion inhibitor system composed of sodium thiosulfate, sodium molybdate, and sodium 2-mercaptobenzothiazole (Fire-Trol 931-J). The manufacturer encountered problems with the latter ingredient while blending the concentrate (the dust caused irritation to personnel when the dry material was being added to the liquid concentrate). Therefore, the mercaptobenzothiazole was dropped from the formulation.[6] The resultant formulation (Allied Poly-N 10-34-0, sodium thiosulfate and sodium molybdate corrosion inhibitors, attapulgite clay, and iron oxide coloring) has never been submitted to and tested by the Forest Service. The inhibitor system, however, satisfied the environmental and health hazard concerns of The Dalles personnel and others but likely exceeds the corrosion rate requirement of less than 1 mil/yr on Al-2024-T3 (previous corrosion tests on Fire-Trol 931-J indicated a corrosion rate of approximately 5 mils/yr).

In November 1973, Chemonics Industries submitted a Fire-Trol 931-L (APP) containing sodium ferrocyanide (YP soda)[7] as a corrosion inhibitor for the Allied Poly-N 10-34-0 formulation. The new inhibitor reduced the corrosion rate as tested in accordance with specifications to $\leq$1 mil/yr. This formulation has been tested by the Northern Forest Fire Laboratory and San Dimas Equipment Development Center and is one of the primary formulations whose performance is outlined later in this report. This formulation, however, was not being used operationally from air tankers. The Boise National Forest (air tanker base at Boise, Idaho), rather than using Allied Poly-N 10-34-0, was using a

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[5] "Laboratory investigation of fire retardant-caused corrosion," study plan 2107-500, on file at the Northern Forest Fire Laboratory, Missoula, Montana, and Forest Service contract 26-3250 to Ocean City Research Corporation, Ocean City, New Jersey.

[6] Private communication with Kathy Lacey, Chemist, Chemonics Industries, October 1974.

[7] Chemonics Industries has a patent pending for use of sodium ferrocyanide inhibitor in ammonium polyphosphate base forest fire retardants.

Simplot-produced superphosphoric acid which was being ammoniated by local fertilizer dealers under verbal agreement to Chemonics Industries (Feed Service, Caldwell, Idaho, was formulating Fire-Trol 931-P utilized at the Boise Air Tanker Base).[8]

Because fire and fuel characteristics and retardant drop conditions often vary and have different requirements, a system which would allow independent selection of the salt content and rheological properties (especially effective viscosity) potentially provides the fire control specialist with the capability to tailor the retardant properties to the specific fire situations. This concept was discussed in an article "Liquids fight forest fires" published in *Fertilizer Solutions* magazine (November-December 1971) with a headline: "Searching for new fire retardant system, the Forest Service challenges the liquid fertilizer industry to produce a better product..." (George 1971b).

Chemonics Industries decided to meet this challenge and began the research and development for a new thickened APP retardant system. This decision was stimulated by the Bureau of Land Management (BLM) fire control personnel at Boise, Idaho, who recognized the need for improving the drop characteristics of the unthickened APP being used, and requested such a product. These personnel had experienced excessive dispersion and drift, resulting in reduced effectiveness under some conditions and fire situations. The thickened APP formulations previously evaluated were considered first (invert-emulsion-thickened 10-34-0 systems produced by both Petrolite Corporation and Stull Chemical Company had previously been evaluated in the laboratory and during drop tests at Porterville, California). In drop tests, the invert-emulsion-thickened retardants showed poorer drop characteristics than the gum-thickened retardants, although all were superior to the unthickened APP solutions. (1972 Marana drop tests. Data on file at the Northern Forest Fire Laboratory, Missoula, Montana.) Test drops of Petrolite-thickened Fire-Trol APP solutions on actual fuels indicate that damage to vegetation (including mature trees) may result--probably caused by the Petrolite thickening agent (inverter). Chemonics Industries has terminated tests until the cause for the apparent toxicity has been determined.

In November 1973, Chemonics Industries submitted two thickened APP retardant formulations: gum-thickened Fire-Trol 931-L and Petrolite invert-emulsion-thickened Fire-Trol 931-L. After preliminary laboratory tests were completed, cooperative agreements were entered between Chemonics Industries and the Intermountain Forest and Range Experiment Station, Northern Forest Fire Laboratory; planning for immediate drop testing began.[9]

Drop tests with the new thickened APP products were conducted at Marana, Arizona, during January and February 1974. Analysis of test results indicated that gum-thickened Fire-Trol 931-L was superior to the invert-emulsion-thickened Fire-Trol 931-L, and that a 2,000 cP apparent viscosity for the gum-thickened solutions gave approximately the same drop performance as the previously quantified gum-thickened Phos-Chek XA fire retardant. (The drop performance of the gum-thickened Fire-Trol 931-L is shown in Section 3.1.15., Air Drop Characteristics.)

The BLM and Boise National Forest decided to evaluate the gum-thickened Fire-Trol 931-L operationally during the 1974 fire season at Boise. Fire-Trol 931-L was not being used, but it was expected that drop characteristics would be similar to those of the product being used (Fire-Trol 931-P; and thus gum-thickened Fire-Trol 931-P). The major problem at this point was the development of a proportioning system for the gum thickener which would provide adequate quality control at preselected levels of gum and APP concentration. Chemonics and Developmental Sciences Incorporated developed such a system and installed it at the Boise base. Although the equipment was used operationally, there were problems in maintaining accurate, reliable control of the chemical and physical retardant properties at preselected levels. When the retardant quality was known, fire control personnel were able to perform adequate on-the-fire evaluations. They concluded that gum-thickened retardants definitely improved retardant drop characteristics and on-site fire retarding effectiveness.[10] (During operational evaluation, a goal was to achieve effectiveness from higher and safer average drop heights between 150 and 300 feet.)

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[8] Private communications with representatives of the companies mentioned. Fire-Trol 931-P is presently being evaluated by the Northern Forest Fire Laboratory and the San Dimas Equipment Development Center.

[9] Cooperative agreements are outlined in INT Study Plan 2107-17G, on file at the Northern Forest Fire Laboratory, Missoula, Montana.

EVALUATION OF FIRE-TROL 931 APP FORMULATIONS

The performance of the Fire-Trol 931-APP formulations that have been evaluated is given in this section. The evaluation was performed as specified in Forest Service Specification 5100-00302a unless otherwise noted. *(The paragraph numbers refer to qualification requirements as outlined in the specification.)*

Storage (3.1.1.)

Requirements: The liquid concentrate shall be stored in two 10-gallon sealed, mild steel containers for a period of 1 year. One container shall be subjected to outside environmental conditions at Missoula, Montana, and the other container subjected to outside environmental conditions at San Dimas, California (fig. 1). After 1-year storage, the liquid concentrate must meet all requirements defined in the specification, and the "mixed retardant" (liquid concentrate mixed with water according to retardant proportions specified by the manufacturer) shall meet the requirements related to viscosity (3.1.3.), separation (3.1.12.), and spoilage (3.1.13.). The mixed retardant shall not exhibit more than 5 percent by volume separation for a period of 4 hours after mixing (temperature at 75 ±5° F).

Performance: Fire-Trol 931-L, 931-N, 931-P, and thickening agents are currently being stored at Missoula and San Dimas. Storage tests were initiated shortly after the dates submitted samples were received, as follows:

	Sample	*Date received*	*Date storage tests initiated*
APP concentrates	-Fire-Trol 931-L	1/2/74	8/1/74
	-Fire-Trol 931-N	5/5/74	8/1/74
	-Fire-Trol 931-P	7/26/74	8/1/74
Thickening agents	-Liquid gum thickener	7/29/74	8/1/74
	-Petrolite invert emulsifier	3/3/74	8/1/74

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[10] Personal communication with Bureau of Land Management Fire Management personnel.

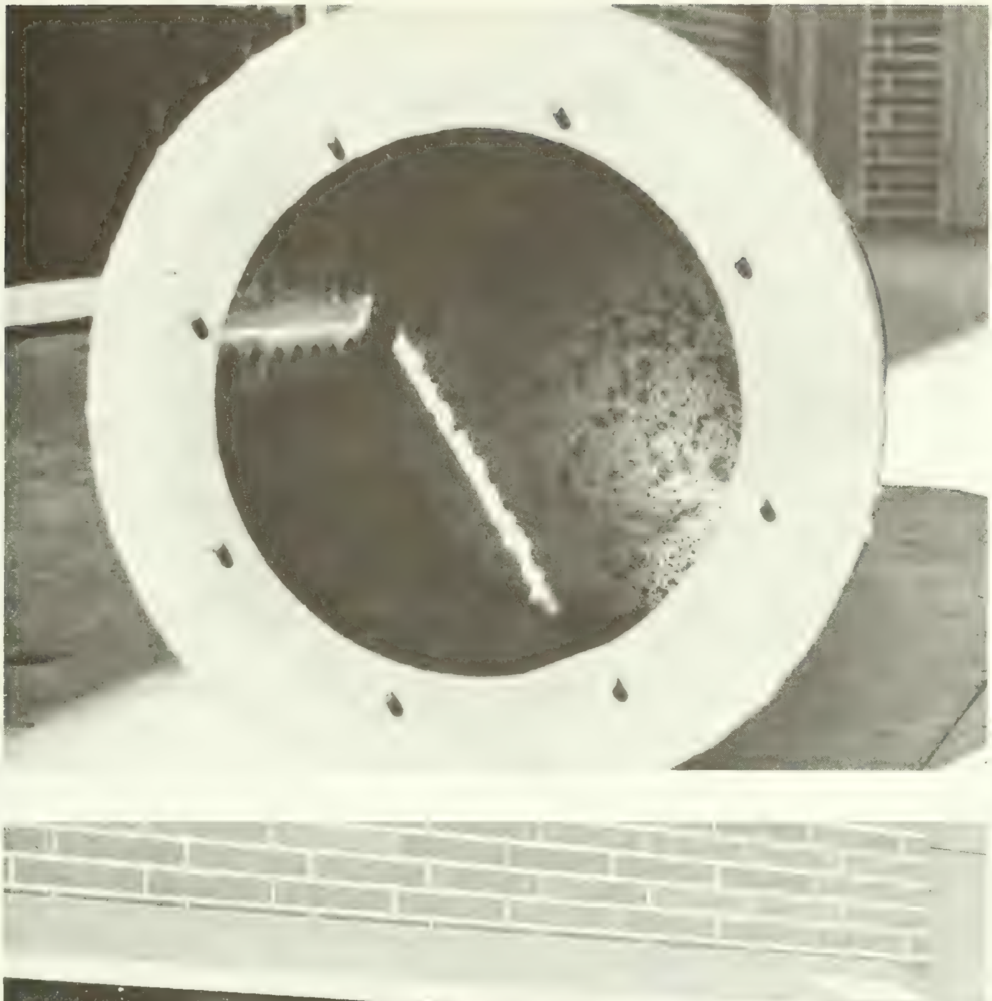

Figure 1.--Mild steel storage container (10 gallon) with plexiglass slot for visually inspecting the retardant during the long-term storage tests (above). Outdoor storage rack containing 10-gallon retardant storage samples (below).

Liquid concentrate storage (4.3.1.1.): The performance of the liquid concentrate and the mixed retardant (prepared from the stored concentrate) has been determined during the prescribed storage period. Visual inspection revealed slight separation in the APP concentrate samples. Color gradations are present and may indicate a separation of colloidal particles by size class. A typical blue color (due to presence of the sodium ferrocyanide corrosion inhibitor) is evident where the liquid and the mild steel are in contact as well as on the surface of the liquid.

The Petrolite invert emulsifier showed complete solution stability. The liquid gum thickener, however, had significant separation--the gum settled from the upper 20 percent of the liquid carrier. The gum thickener alone does not meet the storage requirements.

Mixed retardant storage (4.3.1.2.): The mixed retardant was stored in 1-quart glass jars, half of them containing a mild steel coupon (1 by 1 by 1/8-inch in size). This test was conducted on a sample prepared from the stored concentrate; however, separation performance was not expected to be significantly different. The separation rate for all mixed retardant samples tested indicates that the solution is not stable (>5 percent separation) for 4 hours after mixing (discussed further under Separation, 3.1.12.). The mixed retardant therefore does not meet the requirements for storage.

Specific Weight (3.1.2.)

Requirements: The liquid concentrate and the mixed retardant will be tested for specific weight at room temperature (70 ± 5° F). A test sample of the retardant solution will be allowed to sit for at least 1 hour to allow egress of any entrained air. The specific weight will be determined using a pycnometer or by accurately weighing a gallon of the solution. The specific weight of the mixed retardant shall not exceed 9.5 pounds/gallon.

Performance: The specific weight of the concentrates, mixed retardants, thickening agents, and thickened retardant solutions is:

	Specific weight	
Retardant	*Concentrate (Lb/gal)*	*Mixed retardant @ 4:1 dilution rate (Lb/gal)*
Fire-Trol 931-L	12.32	9.19
Fire-Trol 931-N	12.16	9.21
Fire-Trol 931-P	12.23	9.22
Liquid gum thickener	10.00	
Petrolite inverter	6.93	
Gum-thickened Fire-Trol 931-L (1.5 percent gum)		9.21
Petrolite-thickened Fire-Trol 931-L (4 percent Petrolite inverter)		9.20

Because the Fire-Trol 931-APP solutions can be used effectively at concentrations (dilution rates) other than the standard 4:1 concentration, it is often necessary to relate specific weights to dilution rates and salt concentrations (P_2O_5 equivalent). A standard procedure for determining the salt content in the field (George 1971a) is to use calibration tables that correlate specific gravity of a prepared filtrate solution to salt content and dilution rate. Such tables for calibration and field determination of salt content and thus retardant quality have been determined for Fire-Trol 931-L, 931-N, and 931-P. Although calibration tables are slightly different for the three formulations, the differences are probably not significant for quality control purposes in the field. Table 2 provides the data for Fire-Trol 931-P (which represents approximate mean values for the three products). The lined area indicates a satisfactory salt content exists and no adjustment is needed. The satisfactory salt content was determined by allowing approximately a 10 percent

Table 2.--*Fire-Trol 931-P salt content as related to specific gravity*[1]

Dilution rate[2]	Measured specific gravity of filtrate	Percent P_2O_5 equivalent (by weight)	Percent DAP $(NH_4)_2HPO_4$ (by weight)
10:1	1.043	4.1	7.6
9:1	1.047	4.4	8.2
8:1	1.053	4.9	9.1
7:1	1.060	5.5	10.2
	1.065	5.9	11.0
6:1	1.069	6.2	11.6
	1.070	6.3	11.8
	1.073	6.6	12.2
	1.075	6.7	12.5
5:1	1.080	7.2	13.3
	1.085	7.5	14.1
	1.090	8.0	14.9
	1.095	8.4	15.6
4:1	1.096	8.5	15.8
	1.100	8.8	16.4
	1.105	9.2	17.2
	1.110	9.6	17.9
	1.115	10.1	18.7
3:1	1.119	10.4	19.3
	1.120	10.5	19.5
	1.125	10.9	20.3
	1.130	11.3	21.0
	1.135	11.7	21.8
	1.140	12.1	22.6
	1.145	12.5	23.3
	1.150	13.0	24.1
2:1	1.155	13.4	24.9
	Expanded scale		
	1.175	15.0	28.0
	1.200	17.1	31.8
1:1	1.221	18.8	35.1
	1.225	19.2	35.7
	1.250	21.3	39.5

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[1] The recommended use level for Fire-Trol 931-P is four parts water to one part concentrate (by volume). An adequate specific gravity and salt content corresponding to this use level is outlined within the table. Values for salt content were determined from the equation: Percent P_2O_5 equivalent = 83.02 specific gravity - 82.51.

[2] Ratio of volume of water added to volume of concentrate.

deviation above and below the recommended salt content. (Values in this table are slightly different from those previously published (George 1971a), due to differences in the basic types of 10-34-0 APP and the formulation (corrosion inhibitors, coloring agents, and other additives).) All of the retardants tested meet the requirement for specific weight.

Viscosity (3.1.3.)

Requirements: The viscosity of the liquid concentrate and the mixed retardant will be determined before and after the storage period outlined under Storage (3.1.1.). The viscosity of thickened APP samples as mixed for use will be determined at appropriate time intervals depending on the stability of thickened slurry; thus, defining a viscosity versus time following mixing curve. The viscosities will be determined using a Brookfield Viscometer, Model LVT or LVF, at 60 r/min with the appropriate spindle. (Spindle No. 2 for viscosities 1-500 cP, spindle No. 4 for viscosities greater than 500 cP.) An average viscosity will be determined from three readings on 1,000 ml retardant samples held at a temperature of 70 ± 5° F. The viscosity of the mixed retardant shall not exceed 200 centipoise and the viscosity of gum-thickened APP solutions shall be 1,000-2,000 cP. (No specification exists for a thickened liquid retardant. It is assumed performance requirements shall be the same as those for a thickened, dry chemical retardant (Forest Service Specification 5100-00301). This assumption is made because on-site retardant requirements should be the same for a solution regardless of whether it was prepared from a liquid or dry ammonium phosphate salt.)

Performance: The average viscosities of the Fire-Trol 931 APP concentrate and "mixed retardant" are given below:

Retardant	*Brookfield viscosity* (cP)
Fire-Trol 931-L (concentrate)	4,336
Fire Trol 931-L (mixed 4:1)	81
Fire-Trol 931-N (concentrate)	3,661
Fire-Trol 931-N (mixed 4:1)	22
Fire-Trol 931-P (concentrate)	2,263
Fire-Trol 931-P (mixed 4:1)	34
Gum thickener (concentrate)	4,557 (sample #1) 2,326 (sample #2)
Petrolite invert emulsifier (concentrate)	32

The viscosities of the concentrate Fire-Trol 931 APP solutions vary considerably, as shown by the data above. The viscosity of these solutions is a function of the amount of shear or mixing given the solution during its preparation. As noted by their composition (appendix A), these solutions contain attapulgite clay, which derives its viscosity by separation of lattice layers and inclusion of water between these layers. The degree of separation of these layers is determined by the amount of shear given the clay. A viscosity of at least 1,500 cP is required for the resulting slurry to maintain a stable colloidal suspension.

The viscosity of the diluted mixed solution (unthickened) is a function of the dilution rate or salt concentration and the initial viscosity of the concentrate. Figure 2 shows a plot of the viscosities of Fire-Trol 931-L, 931-N, and 931-P as a function of dilution rate. Although differences in viscosity can be seen, it is very doubtful that these viscosity changes significantly affect mixing, pumping, drop characteristics, and distribution within the fuel complex.

The viscosity of the gum-thickened Fire-Trol 931 APP solutions is a function of the dilution rate of the retardant, the amount or concentration of the gum thickener

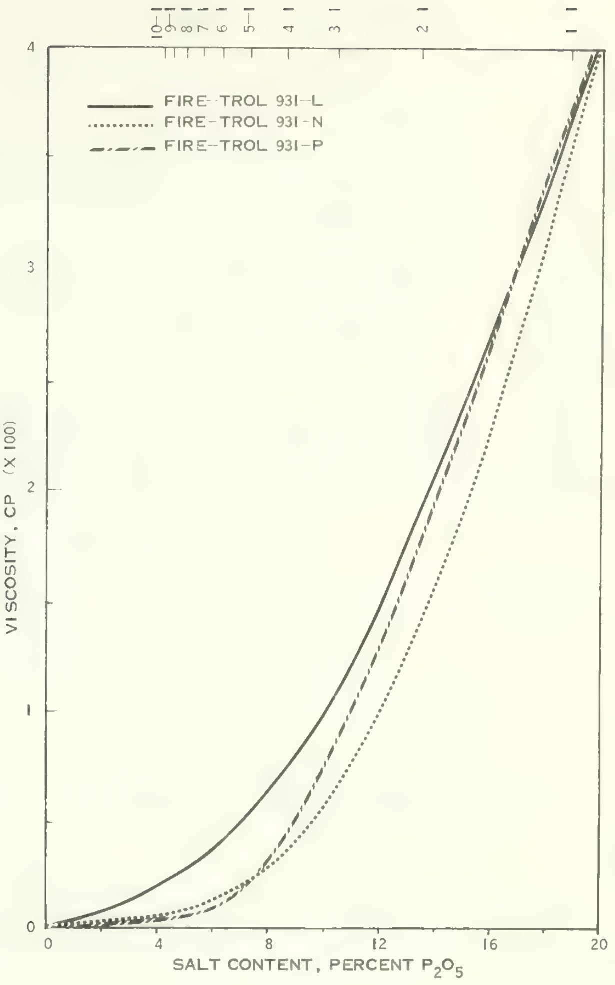

Figure 2.--Viscosity of unthickened Fire-Trol 931-L, 931-N, and 931-P as a function of retardant salt content.

used, and the hydration time following mixing (the hydration rate is also a function of the mixing history--shear rate, time, etc.). Figures 3, 4, and 5 indicate the effect of gum concentration and hydration time on the viscosity development of three different dilutions of Fire-Trol 931-L (2:1, 4:1, 6:1). Similar curves are being developed for Fire-Trol 931-N and Fire-Trol 931-P. Although slight differences in viscosity are expected for the latter two products (due to differences in the basic 10-34-0 solutions), the quality of the gum concentrate will likely be more important. Storage tests to date indicate the quality of the gum concentrate affects the resulting viscosity and the stability of the solution to a greater degree than does the type of 10-34-0. This effect is shown by comparing viscosities (measured after 1 hour and the maximum viscosity developed) for samples of Fire-Trol 931-L diluted 4:1 containing 1.5 percent of gum thickener which had been stored for various lengths of time:

Length of gum storage (*Weeks*)	*Viscosity at 1 hour* (*cP*)	*Maximum viscosity developed* (*cP*)
- - - - - Fire-Trol 931-L 4:1 + 1.5 percent gum thickener - - - - -		
0	1,200	1,670
4	900	>900
7	957	1,143
9	1,013	1,240
18	990	1,110

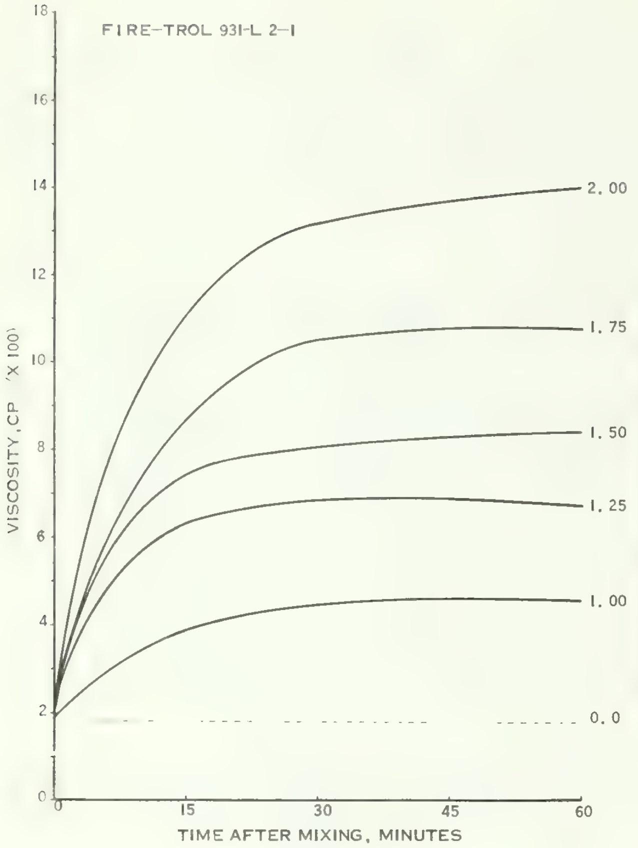

Figure 3.--The effect of time following mixing (hydration time) on the viscosity of a Fire-Trol 931-L solution (2:1 dilution) for several concentrations of gum thickener.

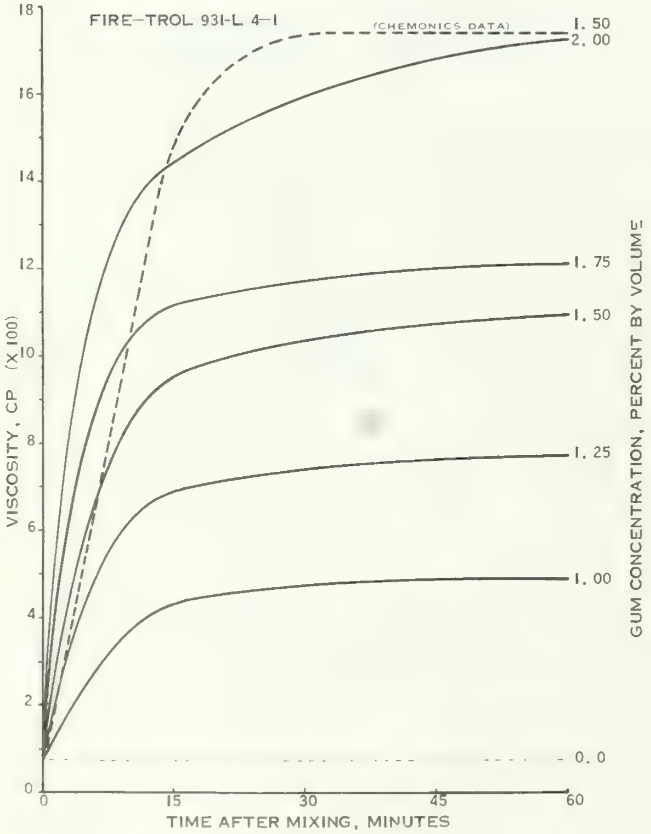

Figure 4.--The effect of time following mixing (hydration time) on the viscosity of a Fire-Trol 931-L solution (4:1 dilution) for several concentrations of gum thickener.

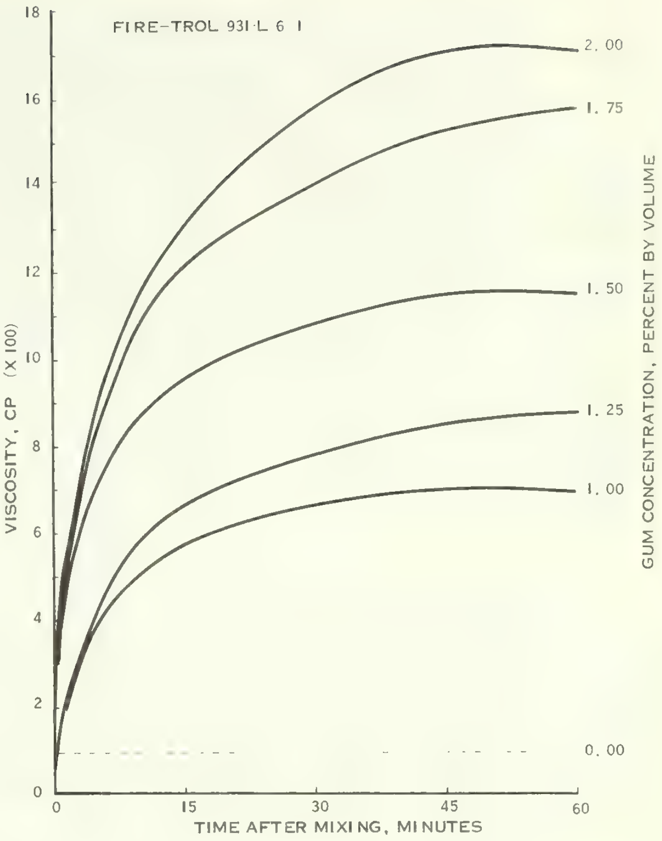

Figure 5.--The effect of time following mixing (hydration time) on the viscosity of a Fire-Trol 931-L solution (6:1 dilution) for several concentrations of gum thickener.

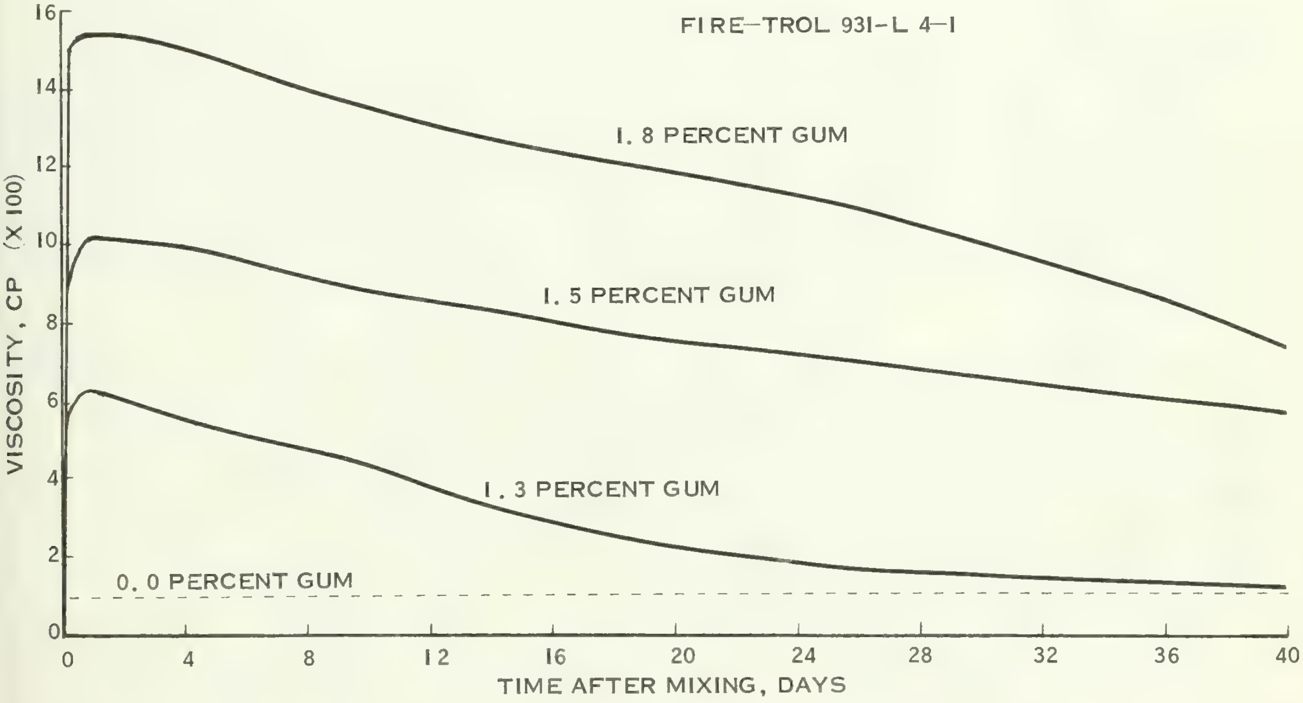

Figure 6.--The effect of storage time (time after mixing) on the viscosity of 4:1 dilution of Fire-Trol 931-L containing gum thickener at several concentrations.

As previously noted, the storage requirement for an unthickened mixed retardant is a 4-hour stability period (separation <5 percent at the end of 4 hours), while for a thickened mixed retardant the solution must maintain stability for 1 year. Because of the demand mixing capability with the thickened liquid system and the frequent practice of having air tankers stand by loaded, an intermediate storage requirement might be warranted (such as 2 weeks to 1 month solution stability). In view of the differing requirements for the dry-type thickened retardant and the unthickened liquid retardant, storage stability was quantified over a period of time covering both requirements. The viscosity of Fire-Trol 931-L mixed at a dilution of 4:1, with various concentrations of gum thickener and shown as a function of time since mixing, is given in figure 6. The 1.5 and 1.8 percent gum mixtures thicken to over 1,000 cP within the first hour; they drop below that level in 4 and 30 days, respectively.

Unthickened Fire-Trol 931-L, 931-N, and 931-P meet the viscosity requirement of less than 200 cP. When thickened, Fire-Trol 931-L does not fulfill the requirement for thickened retardants (dry retardant specification) because of the decrease in viscosity during the first 4 days.

Corrosion (3.1.4.)

Requirements (uniform corrosion and pitting tendency 3.1.4.1. and 3.1.4.2.): The liquid concentrate and mixed retardant for aerial application (type A) and ground application (type G) will be tested for uniform corrosion and pitting tendency using a corrosion rate meter (Magna corrater, or equal). The alloy to be tested will be used as the electrode probes in determining the uniform corrosion rate and the pitting tendency. Aluminum alloy 2024-T3 will be used for both type A and type G retardants. In addition to Al-2024-T3, type G retardants will be tested using probes of mild steel AISI C-1010 and naval brass.

The appropriate metal probe will be immersed in the retardant test sample under static conditions for 16 hours. The conditioned probe will then be immersed into the sample under dynamic conditions (sample rotating at 1 r/min) for 8 hours, and then gently rinsed with lukewarm water. After the probes have dried, they will be reimmersed in the sample and monitored for an additional 8 hours, after which they will be rinsed with a high pressure stream of water to simulate actual aircraft washdown. The probes will be dried again, and then immersed under dynamic conditions for an additional 8 hours The uniform corrosion rate will then be determined. The uniform corrosion rates for type A concentrate or mixed retardants shall be ≤ 1 mil/yr (0.001 in/yr) and for type G concentrate or mixed retardants shall be ≤ 3 mils/yr (0.003 in/yr). The pitting tendency for both type A and G retardants shall not exceed a factor of 5.0.

Performance (uniform corrosion and pitting tendency 3.1.4.1. and 3.1.4.2.): The average uniform corrosion rate and pitting tendency for several Fire-Trol 931 APP concentrates and mixed retardants on aluminum 2024-T3 are given in table 3. This table includes several dilution rates other than the standard 4:1 dilution, since the manufacturer suggests possible use of various dilution rates in addition to the 4:1 dilution rate. Figure 7 shows that as the concentration of Fire-Trol 931-L is increased from 25:1 to 10:1 the uniform corrosion rate on Al-2024-T3 increases. With additional increases in concentration beyond 10:1, the uniform corrosion rate decreases. To determine this relationship for each retardant formulation would require a very large number of tests and considerable time; therefore, only comparative data at selected dilution rates have been determined for Fire-Trol 931-N and 931-P (table 4). At all concentrations tested, Fire-Trol 931-N is either under or just slightly over 1 mil/yr and all Fire-Trol 931-P concentrations tested are under 1 mil/yr.

Table 3.--*Uniform corrosion rates and pitting tendency on Al-2024-T3 alloy for Fire-Trol APP retardant solutions tested*

Retardant	Concentrate			Diluted for use			
	Number of runs	Uniform corrosion rate	Pitting tendency	Dilution rate	Number of runs	Uniform corrosion rate	Pitting tendency
		(mils/yr)				*(mils/yr)*	
Fire-Trol 931	2	0.5	0.07	4-1	5	5.5	5.4
Fire-Trol 934	1	.42	1.4	4-1	1	4.9	2.5
Fire-Trol 931-A	1	7.9	.8	4-1	1	14.0	4.0
Fire-Trol 931-B	2	.24	.55	4-1	2	2.6	1.4
Fire-Trol 931-C	2	.09	.16	4-1	2	2.9	1.2
Fire-Trol 931-D	2	.74	.31	4-1	2	2.1	.4
Fire-Trol 931 Dryden, Canada	1	.75	1.07	4-1	1	3.4	.5
Fire-Trol 931-E	9	.3	.15	4-1	6	1.1	.1
Fire-Trol 931-F	9	.45	.19	4-1	6	2.5	.2
Fire-Trol 931-J	6	2.0	.8	4-1	6	4.4	.9
Fire-Trol 931-L	3	.23	.15	4-1	18	.79	1.78
do.				7-1	6	.93	1.99
do.				6-1	9	.73	2.59
do.				5-1	6	.48	1.31
do.				3-1	3	.13	.63
do.				2-1	3	<.1	.47
do.				10-1	3	1.13	1.7
do.				25-1	6	.73	4.35
Fire-Trol 931-N	3	.07	3.23	4-1	16	.85	2.87
do.				7-1	6	1.01	1.20
do.				6-1	6	.55	.66
do.				5-1	9	1.01	1.44
do.				3-1	6	1.27	2.42
Fire-Trol 931-P	6	.37	.47	4-1	12	.48	1.70
do.				7-1	6	.35	.93
do.				6-1	9	.88	.79
do.				5-1	6	.69	1.17
do.				3-1	6	.62	1.10

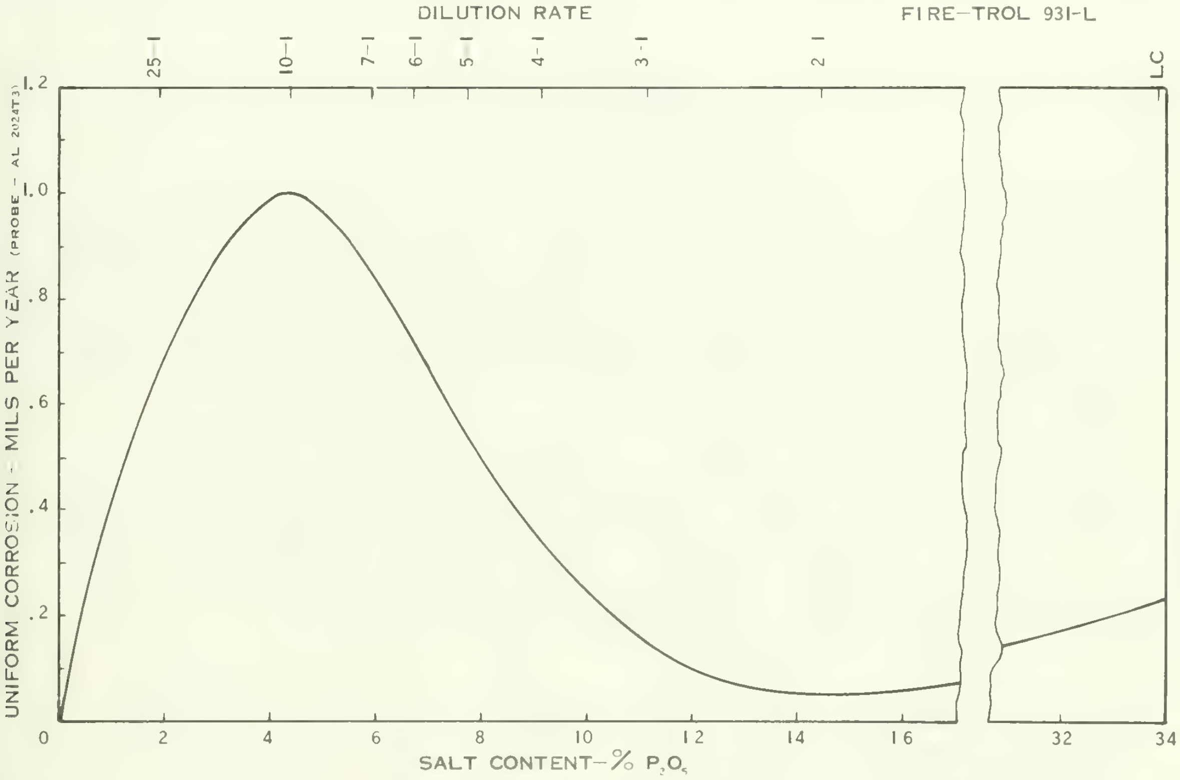

Figure 7.--Uniform corrosion rate of Al-2024-T3 as a function of salt content for Fire-Trol 931-L.

Table 4.--*Uniform corrosion rates and pitting tendency on Al-2024-T3 alloy for unthickened Fire-Trol 931-N and 931-P.*

Dilution rate	Analyzed salt content	Number of runs	Uniform corrosion	Pitting tendency
	Percent P_2O_5		*Mils/yr*	
		FIRE-TROL 931-N		
H_2O	0.0	3	0.104	0.06
7:1	5.66	6	1.01	1.20
6:1	6.43	6	.55	.66
5:1	7.23	9	1.01	1.44
4:1	8.66	16	.85	2.87
3:1	10.77	6	1.27	2.42
Conc.	32.67	3	.07	3.23
		FIRE-TROL 931-P		
H_2O	0.0	3	.104	.06
7:1	5.71	6	.35	.93
6:1	6.69	9	.88	.79
5:1	7.64	6	.69	1.17
4:1	8.84	12	.48	1.70
3:1	10.41	6	.62	1.10
Conc.	32.41	6	.37	.47

Similar corrosion tests were run on gum-thickened Fire-Trol 931-L, as well as the concentrated liquid gum-thickening agent and the Petrolite inverter. The results of these corrosion tests are given in table 5. Corrosion rates for gum-thickened Fire-Trol 931-N and 931-P, mixed 4:1, are also given. One 2:1 dilution and a 6:1 dilution of Fire-Trol 931-L have uniform corrosion rates above 1 mil/yr. All other mixtures with various dilution rates and amounts of gum thickener have corrosion rates less than 1 mil/yr.

Although Fire-Trol 931 is considered a type A retardant (for aerial application) and not normally for use as a type G retardant (for ground application), several tests were run on the alloys specified for type G retardants (mild steel, brass, and zinc [3.1.4.2.]). Corrosion rates for these alloys when exposed to several Fire-Trol 931 formulations are given in table 6. On brass and 1010 steel, only Fire-Trol 931-N concentrate has a corrosion rate higher than 1 mil/yr. All materials tested on zinc show high corrosion rates of over 450 mils/yr.

The investigation of retardant-caused corrosion performed by Ocean City Research Corporation (Gehring 1974) has better defined the effects of these formulations on several types of corrosion; i.e., uniform or general, galvanic, crevice, fatigue, stress, etc. Although current retardant specifications do not contain requirements for corrosion other than those outlined in this section for uniform corrosion and pitting tendency (3.1.4.2.) and intergranular corrosion (3.1.4.3.), the corrosion characteristics of

Table 5.--*Uniform corrosion rates and pitting tendency on Al-2024-T3 alloy for gum-thickened Fire-Trol 931-L, 931-N, and 931-P*

Retardant	Dilution rate	Amount of gum	No. of runs	Uniform corrosion	Pitting tendency
		(Percent by weight)		*(Mils/yr)*	
Petrolite inverter	Conc.		3	0.20	0.83[1]
Gum thickener (old drum)	Conc.		3	<.01	.1
Gum thickener (new drum)	Conc.		3	<.01	.03
Fire-Trol 931-L	2:1	1.3	3	1.58	1.73
do.	2:1	1.5	3	.31	.63
do.	2:1	1.8	3	.29	.55
do.	3:1	1.3	3	.32	.22
do.	3:1	1.5	3	.19	.44
do.	3:1	1.8	3	.18	1.32
do.	4:1	1.3	3	<.01	1.30
do.	4:1	1.5	3	<.01	2.00
do.	4:1	1.8	5	.24	.60
do.	5:1	1.3	3	.05	.58
do.	5:1	1.5	3	.21	.24
do.	5:1	1.8	2	.21	.075
do.	6:1	1.3	3	<.01	3.33
do.	6:1	1.5	3	.17	1.67
do.	6:1	1.8	3	1.12	.74
Fire-Trol 931-N	4:1	1.3	3	.25	.51
Fire-Trol 931-P	4:1	1.3	3	.81	1.08

[1] Visual inspection of Corrater probes following these tests indicates significant pitting although the instrument data indicated a pitting tendency of 0.83.

Table 6.--*Uniform corrosion rates and pitting tendency on zinc, brass, and (1010) steel for Fire-Trol 931 formulations tested*

Retardant	Dilution rate	Number of runs	Uniform corrosion	Pitting tendency
			Mils/yr	
		ZINC		
Fire-Trol 931-D	4:1	3	456	90
Fire-Trol 931-L	Conc.	3	921	0
Fire-Trol 931-L	4:1	3	initial rate >1000 mil/yr	
		BRASS		
Fire-Trol 931-D	4:1	3	0.94	0.9
Fire-Trol 931-L	Conc.	3	.15	.03
Fire-Trol 931-L	4:1	3	.43	.1
Fire-Trol 931-N	Conc.	3	.897	.09
Fire-Trol 931-N	4:1	3	.637	.17
Fire-Trol 931-P	Conc.	3	.056	.05
Fire-Trol 931-P	4:1	3	.148	.06
		1010 STEEL		
Fire-Trol 931-D	4:1	3	.86	.30
Fire-Trol 931-L	Conc.	3	.17	.18
Fire-Trol 931-L	4:1	3	.56	.87
Fire-Trol 931-N	Conc.	3	1.88	1.56
Fire-Trol 931-N	4:1	3	.581	.062
Fire-Trol 931-P	Conc.	3	.418	.43
Fire-Trol 931-P	4:1	3	.916	.04

these products and alloys are of considerable interest to retardant users. Therefore, test results and subsequent recommendations are summarized in the discussions and in appendix B.

Requirements (Intergranular Corrosion 3.1.4.3.): Intergranular corrosion will be measured for type A liquid concentrates and the mixed retardant, using U-bend 2024-T3 aluminum test samples. Two individual U-bend samples will be exposed to the retardant by using a 2-hour cycle alternate submersion-immersion machine (2 min retardant exposure; 1 hour 58 min drying period). The U-bend samples will be removed from the retardant after 300 hours of exposure. Two additional U-bend samples will be exposed to the atmosphere for control purposes.

Performance (Intergranular Corrosion 3.1.4.3.): These tests were performed by the San Dimas Equipment Development Center, San Dimas, California. SDEDC reported that "there was no intergranular corrosion caused by Fire-Trol 931-L, 931-N, or 931-P." (Data on file at the Northern Forest Fire Laboratory or San Dimas Equipment Development Center.) (Note: Intergranular corrosion tests were only performed on the liquid concentrate and the mixed retardant at the 4:1 dilution rate.)

pH Values (3.1.5.)

Requirements: The pH of the liquid concentrate and "mixed retardant" shall be between 6.0 and 8.0.

Performance: The pH of the concentrate and mixed solutions of Fire-Trol 931-L, 931-N, and 931-P was determined using a Sargent Model LS pH meter (accuracy ±0.05 pH units). The results given below show that in mix ratios of from 0 parts water with 1 part concentrate to 10 parts water with 1 part concentrate, the pH of all mixtures is between 6.0 and 6.65 except Fire-Trol 931-N concentrate which is 5.82.

Retardant mix ratio (water to conc. by volume)	*pH of solution*		
	Fire-Trol 931-L	*Fire-Trol 931-N*	*Fire-Trol 931-P*
Concentrate	6.10	5.82	6.20
1:1	6.28	6.09	6.33
2:1	6.40	6.19	6.42
3:1	6.43	6.22	6.50
4:1	6.46	6.27	6.51
5:1	6.53	6.32	6.54
6:1	6.52	6.32	6.58
7:1	6.56	6.37	6.59
8:1	6.59	6.39	6.55
9:1	6.53	6.40	6.57
10:1	6.62	6.42	6.65

A plot of the pH as a function of dilution rate (fig. 8), shows a constant decrease in pH from the most dilute to the most concentrated.

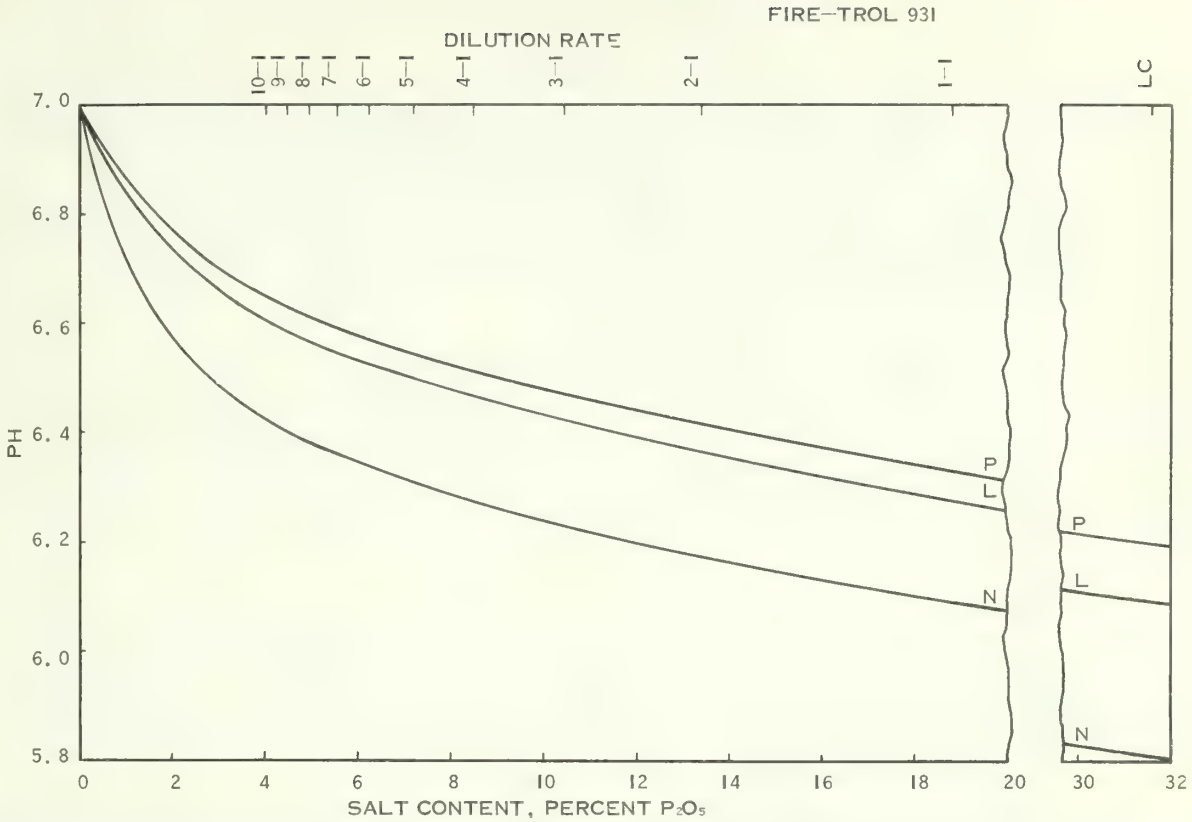

Figure 8.--pH of the retardant solution as a function of dilution rate or salt content.

Abrasion and Erosion (3.1.6.)

Requirements: An aluminum 2024-T3 disc and wear plate will be used to determine abrasion and erosion characteristics of retardant samples. The disc is 4.00 ±0.01 inches in diameter and approximately 5/16 inch thick, with an overall thickness tolerance of ±0.001 inch. The wear plate has a similar thickness; but it is square, with an edge dimension that exceeds the diameter of the disc.

The disc will be mounted on a rotating shaft and positioned parallel to and directly above the stationary wear plate. The uniform space between the disc and wear plate will be 0.020 ± 0.001 inch.

With the disc and wear plate immersed about 2 inches into the retardant sample, the disc will be rotated at 1,800 r/min for 50 hours. Thickness measurements will be taken on the plate and the disc with an average thickness determined. Maximum abrasion shall not exceed 0.010 inch.

Performance: These tests were performed by the San Dimas Equipment Development Center (data on file at the Northern Forest Fire Laboratory and San Dimas Equipment Development Center) and their reports show the total measured wear was 0.0085 inch for 931-L, 0.004 inch for 931-N, and 0.0095 inch for 931-P. All three retardants had less than the maximum allowable 0.010 inch and are, therefore, acceptable.

Apparently only the mixed retardant at a 4:1 dilution ratio was tested. Although the performance of the concentrate and other dilutions is not known, similar performance for these solutions will be required.

Combustion Retarding Effectiveness (3.1.7.)

Requirements: The long-term fire-retarding effect of the retardant will be measured by burning ponderosa pine needle and aspen excelsior fuel beds treated with the mixed retardant. The 8-foot-long, 18-inch-wide, 3-inch-deep fuel beds will be prepared to reproducible specifications using 6 pounds of needles or 4 pounds of excelsior that have been predried to a 5.0 to 7.5 percent equilibrium moisture content. The mixed retardant will be sprayed uniformly into fuel beds at 1 and 2 gal/100-ft^2 levels and then dried until 100 percent of the original moisture has evaporated. The treated beds will then be burned under controlled conditions of 90° F, 20 percent relative humidity, and in a 5 mi/h wind.

The parameters used to determine retardant effectiveness will be rate of fire spread and fire intensity. The rate of spread (Rs) will be measured visually as the flame front moves through the treated fuel. Fire intensity will be determined by measuring fuel rate of weight loss (Rw) during the fire and the residue weight (Rr) after all combustion has stopped. The reduction in spread and intensity rates caused by the retardant treatment will be determined as a percent of untreated values for the same parameters in similar fires.

The retardant will be evaluated by use of a numerical rating called a superiority factor (S.F.). The percent reduction data from all fires will be combined, weighted, and calculated into one numerical factor that can be used to compare a given product to any other tested product. The superiority factor is a numerical index from 0.0 to 1.0. A chemical registering an S.F. of 0.0 would have no retarding effect and a chemical having an S.F. of 1.0 would prevent combustion.

The overall superiority factor is calculated for both fuel types, application rates, and parameters measured by the formula. The equation used to compute superiority factors for each retardant is:

$$\begin{aligned} S.F. = {} & 0.25 \text{ (\% decrease Rs needles)} + 0.25 \text{ (\% decrease Rs exc)} \\ & + 0.125 \text{ (\% decrease Rw needles)} + 0.125 \text{ (\% decrease Rw exc)} \\ & + 0.125 \text{ (\% reduction in fuel consumed needles)} \\ & + 0.125 \text{ (\% reduction in fuel consumed exc).} \end{aligned}$$

For a retardant to be considered effective, its superiority factor, plus the standard error of the mean, must fall between 0.50 and 1.00. (This deviates from the acceptable level of 0.60 given in USDA specifications 5100-00301 and 5100-00302a. The lower acceptance level occurs because an additional fire intensity parameter (residue or fuel consumed) has been added to the superiority factor calculation, thus causing a reduction of approximately 0.10.)

Performance: The superiority factors for Fire-Trol 931-L, 931-N, and 931-P as a function of the amount of chemical applied are shown in figure 9. (The actual data from which the superiority factors were derived are given in appendix C.) Figure 9 also shows the standard DAP superiority factor (George and Blakely 1972) as a function of the grams of P_2O_5/ft^2. To assure comparability of data establishing the standard curve with the fuels and conditions used for evaluating the Fire-Trol APP products, tests using standard DAP solutions were also conducted. The results from these fires are shown as "DAP" points and are shown to fit the previous standard DAP curve very well.

Although the average values for superiority for all parameters, fuels, and concentration levels combined closely fit the standard DAP curves, individual elements often contain significant variation. (See figures in appendix C.) However, the general difference between the Fire-Trol APP solutions and the "DAP" are quite consistent.

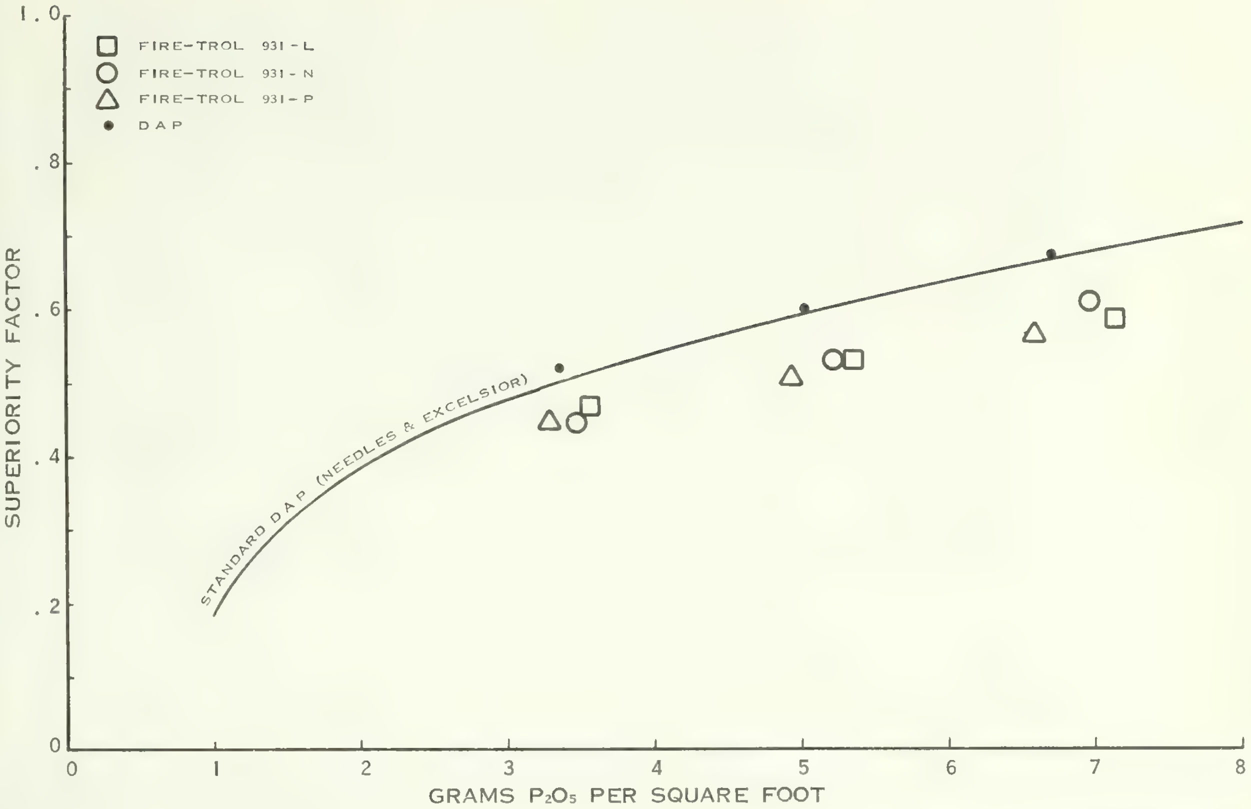

Figure 9.--The superiority factor for Fire-Trol 931-L, 931-N, 931-P, and standard DAP as a function of the amount of chemical applied.

The difference in effectiveness between Fire-Trol 931 APP products and DAP solutions is primarily due to the presence of impurities in Fire-Trol; however, small differences might be attributed to the form and availability of the P_2O_5 (ortho vs. polyphosphate content). Basic green acid 10-34-0 solutions contain small percentages of impurities (table 7) and can tie up the phosphate to form insoluble compounds that may or may not be effective fire retardants. Usually, compounds formed with Fe, Ca, and Mg are ineffective due to their high temperature requirement for decomposition and thus their unavailability especially in terms of altering pyrolysis and combustion reactions.

The data below show the relative efficiency in terms of effectiveness for the Fire-Trol APP and DAP solutions.

	Superiority factor	
	(All treatments, levels, and fuels)	*(Equivalent DAP solution)*
Fire-Trol 931-L	0.53	0.60
Fire-Trol 931-N	.53	.59
Fire-Trol 931-P	.51	.57

Table 7.--*Results of chemical analysis of Fire-Trol 931-L, 931-N, and 931-P*

Element	Method[1]	Liquid concentrate			Mixed 4:1		
		931-L	931-N	931-P	931-L	931-N	931-P
		Percent by weight					
N	1	9.29	9.30	9.30	2.51	2.50	2.50
P_2O_5	1	31.58	31.62	31.62	8.52	8.51	8.49
N	2	9.90	9.69	9.45	2.46	2.55	2.60
P_2O_5	3	31.75	30.00	29.40	8.49	8.28	7.82
					p/m		
Zn	4				30	67	136
Mn	4				30	7.5	12.5
Cu	4				6.5	8.0	16.5
Fe	4				4,863	5,050	5,013
Ca	4				70	61	64
Mg	4				272	176	279
Cr	4				41	66	87
Pb	4				1.5	1.9	2.4
Cd	4				2.5	1.3	16.2
Ni	4				6.0	2.75	16

[1] Method:

1. Calculated from manufacturer's data
2. Micro-Kjeldahl analysis
3. Colorimetric analysis
4. Commercial lab (USTL, Inc.)

In other words, to compare effectiveness, the comparison must be made on more than just the total P_2O_5 equivalent, since the P_2O_5 may or may not be available. For example, the level of phosphate in Fire-Trol 931-L reduced combustion by 53 percent over untreated fuel. Had the same phosphate been "available" as in the DAP solution tested, it would have reduced combustion by 60 percent.

Fire-Trol 931-L, 931-N, and 931-P have a superiority factor of 0.53, 0.53, and 0.51, respectively, when mixed at a 4:1 dilution rate, which is greater than the minimum allowable superiority factor (0.50). However, in dilutions of more than 4:1, the superiority factor will fall below the 0.50 level.

Color (3.1.8.)

Requirements: Type A, air applied, liquid concentrate shall contain sufficient nonstaining coloring agent so that the "mixed retardant" shall contain a minimum of 16 grams of coloring agent (Fe_2O_3) per mixed gallon or equal. Color for type G, ground applied, liquid concentrate is optional. If color is specified, type G liquid concentrate shall contain sufficient nonstaining coloring agent so that the "mixed retardant" shall contain a minimum of 5 grams of coloring agent (Fe_2O_3) per mixed gallon or equal.

Performance: The color composition of each of the Fire-Trol APP solutions is given in appendix A. Using the composition given, the quantity of coloring agent was calculated and is given below:

	Coloring agent	*Quantity (Grams/gallon of mixed retardant)*
Fire-Trol 931-L	Dye	--
	Fe_2O_3	16.15
Fire-Trol 931-N	Dye	--
	Fe_2O_3	16.12
Fire-Trol 931-P	Dye	--
	Fe_2O_3	16.18

Thus, Fire-Trol 931-L, 931-N, and 931-P when mixed at a dilution rate of 4:1 contain at least 16 grams of coloring agent (Fe_2O_3) as required.

Health and Safety (3.1.9.)

Requirements and Performance: USDA specifications 5100-00301 and 5100-00302a contain no requirements for health and safety. However, evaluation procedures usually include review of the composition and a literature search of toxicity information concerning these compounds.

In the case of the Fire-Trol 931 APP formulations, the toxicity of the basic ingredient (10-34-0) is fairly well documented. A partially completed literature review conducted by George (results on file at the Northern Forest Fire Laboratory) and recent studies by the National Marine Fisheries (Blahm and others 1974), indicated and substantiated that the primary environmental impact of the APP solutions is their effect on water quality and marine life. Low concentrations can be toxic to fish and other aquatic organisms. The NH_3 has been determined to be the toxic ingredient and, because of the relative amount of NH_3 contained in the formulations, will usually overshadow the effect of the minor ingredients contained in the formulation. A study by the Pacific Northwest Forest and Range Experiment Station is determining the effects of streamside application of ammonia-based fire retardant on streamwater chemistry and benthic organisms (Study Plan 1602-54, Pacific Northwest Station. Data on file at the Northern Forest Fire Laboratory).

The possible effects of the retardant on human health have been a concern. For example, in the Pacific Northwest Region sodium dichromate corrosion inhibitor was removed from Fire-Trol 931 for operational use after The Dalles (Oregon) City Water Board became concerned about the toxic effects of the sodium dichromate.

When Fire-Trol 931-L was submitted with sodium ferrocyanide as a corrosion inhibitor, the "ferrocyanide" cast some doubt on "health and safety" effects. A thorough literature review and laboratory tests were performed to determine the legitimacy of such doubts and establish what effects might be expected. (Data on file at the Northern Forest Fire Laboratory.) Truesdial Laboratories conducted independent tests and determined that when ferrocyanide was burned, most of the cyanogens became CO_2 rather than poisonous HCN gas. When retardant is applied on wildfires at 2 gal/100 ft^2, the maximum possible HCN given off is 50 mg/m^3 total. Since OSHA allows a maximum exposure level to HCN gas of 11 mg/m^3 in air during a 40-hour work week, no harmful human or environmental effects are expected.

Mixing (3.1.10.)

Requirements: The mixing of unthickened liquid retardants shall be simply by adding water to the liquid concentrate. For thickened liquid retardant the slurry shall reach the accepted viscosity within 4 minutes' mixing time (as prescribed in the "thickened" specification 5100-00301). The accepted viscosities are:

	Viscosity (*cP*)
Gum-thickened retardants (type I)	1,000-2,000
Gum-thickened retardants (type II)	1,500-2,500

Performance: The Fire-Trol 931 APP products can be mixed simply by adding water. However, agitation is required for the solution to be adequately mixed--the active retardant salt evenly distributed throughout the solution. The gum-thickened Fire-Trol 931 APP solutions also require shear or agitation to evenly distribute the low concentration of gum within the diluted APP solution. Obtaining a good uniform quality of the mixed retardant (both salt and viscosity) is a function of the mixing system being used. The performance of the gum in developing the required viscosity is covered in section 3.1.3. (viscosity). The viscosity of the gum-thickened Fire-Trol 931-L does not reach the accepted level in 4 minutes as required in the thickened retardant specification; however, it does reach this level in approximately 15 minutes (probably acceptable performance). Only a few comparative tests were run on hydration times for gum-thickened Fire-Trol 931-N and 931-P, but they showed similar results to the 931-L tests.

Salt Content (3.1.11.)

Requirements: Standard chemical analysis procedures will be used to analyze each liquid concentrate for phosphorous and nitrogen content. A colorimetric method will be used for determining the P_2O_5 (P) equivalent in all ammonium phosphate solutions. A micro-Kjeldahl distillation method will be used to analyze for NH_3 (N) in all ammonium compounds.

To analyze for P_2O_5, a sample (the size depending on the apparent P_2O_5 equivalent) will be digested by a wet process using ternary acid to dissolve all ingredients. To this sample is added perchloric acid and ammonium molybdate. Amino-naphthol-sulfonic acid is then added, and color is allowed to develop for 10 minutes. The optical density at 660 mμ versus a reagent blank is then read, using a Beckman DU spectrophotometer. Using a standard curve, the percent P in the sample can be calculated and the percent P_2O_5 determined.

To analyze for ammonia, samples of the retardant are weighed to ± 0.1 milligram, placed in the distillation apparatus, and the ammonia boiled off and captured in a boric acid solution. The solution is titrated with dilute hydrochloric acid of a known molarity, and the ammonia is calculated and the percent N determined.

The P_2O_5 equivalent salt content of the liquid concentrate shall not be less than 30 percent. After a sample has been stored for 1 year as specified above (3.1.1.), the salt content shall be within ±3 percent of that determined before storage..

Performance: Liquid concentrates of Fire-Trol 931-L, 931-N, and 931-P were analyzed using both the colorimetric and micro-Kjeldahl methods to determine their P_2O_5 and N content. The salt content of the Fire-Trol 931 formulations and the methods used for analysis are given below:

	931-L	*931-N*	*931-P*
Percent P_2O_5, theoretical	31.58	31.62	31.62
Percent P_2O_5, colorimetric	31.75	30.00	29.40
Percent N, micro-Kjeldahl	9.90	9.69	9.45

All three concentrate formulations meet the requirement for 30 percent P_2O_5 when determined by using the manufacturer's theoretical data. When analyzed by the colorimetric method, 931-L and 931-N meet the requirement but 931-P, containing 29.40 percent P_2O_5 content, falls slightly below the required concentration. This, however, is probably not significant unless the retardant combustion effectiveness (superiority factor) falls below the accepted level.

The salt content of Fire-Trol 931-P as a function of dilution rate and specific gravity was given in Section 3.1.2. (specific weight). For quality control purposes in the field it can be assumed, as discussed, that Fire-Trol 931-L and 931-N are similar to 931-P (in other words, use the same calibration table for these three formulations).

When checks were made for "salting out" of 931 formulations stored over an 8 to 18 month period, salt concentration had not changed.

Separation (3.1.12.)

Requirement: Two quarts of liquid concentrate will be mixed to the manufacturer's recommended proportions and placed in unsealed (loosely covered) glass quart jars. The concentrate will sit undisturbed for 1 year, be inspected periodically, and the separation of components measured and recorded. Two quarts of freshly mixed retardant will also be placed in glass jars and sit undisturbed for 4 hours. The separation of components will be measured with a linear scale and recorded every 15 minutes. Neither the liquid concentrate nor the mixed retardant shall display any visual division of one or more components (for example, the thickening agent, coloring agent, etc.) within the sample amounting to more than 5 percent by volume.

Performance: Fire-Trol 931 APP products are designed to be diluted to different concentrations on demand; therefore, separation tests were performed using several dilutions of the three concentrates: Fire-Trol 931-L, 931-N, and 931-P. The formulations were tested unthickened, at dilutions of 2:1, 3:1, 4:1, 5:1, 6:1, and 7:1. The amount of separation occurring following the mixing of the three formulations as a function of time is shown in figures 10 through 16. In the first three figures (10, 11, 12) an expanded scale is used to show the amount of separation prior to the 4 hour period--less than 5 percent separation should occur at that point. Actually, all three products separate to a greater extent than allowed--depending on the dilution.

Figures 13, 14, and 15 show the extent of separation during storage up to 40 days. In general, the separation rate decreases after several days (approximately 4 days for 4:1 dilutions) and the total separation is from 40 to 60 percent shortly thereafter.

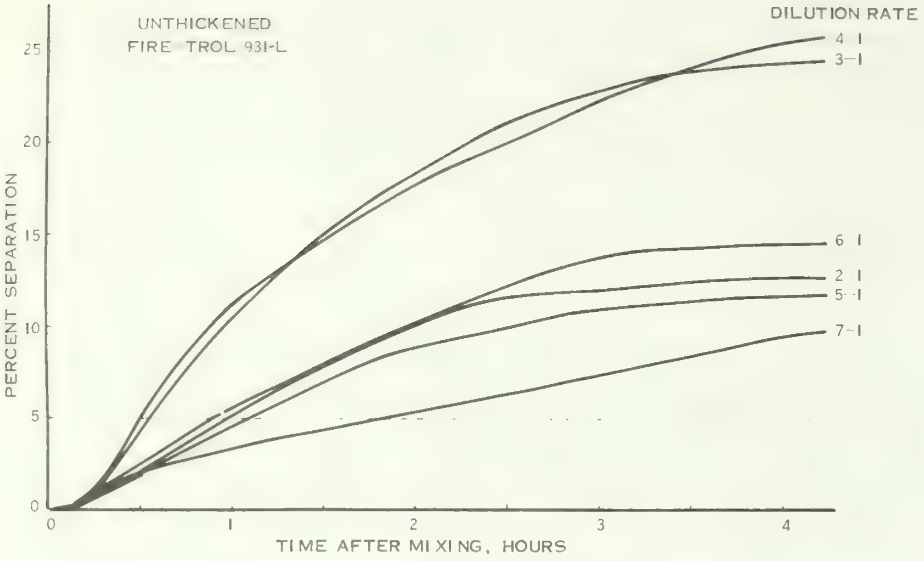

Figure 10.--Separation of unthickened Fire-Trol 931-L as a function of time after mixing.

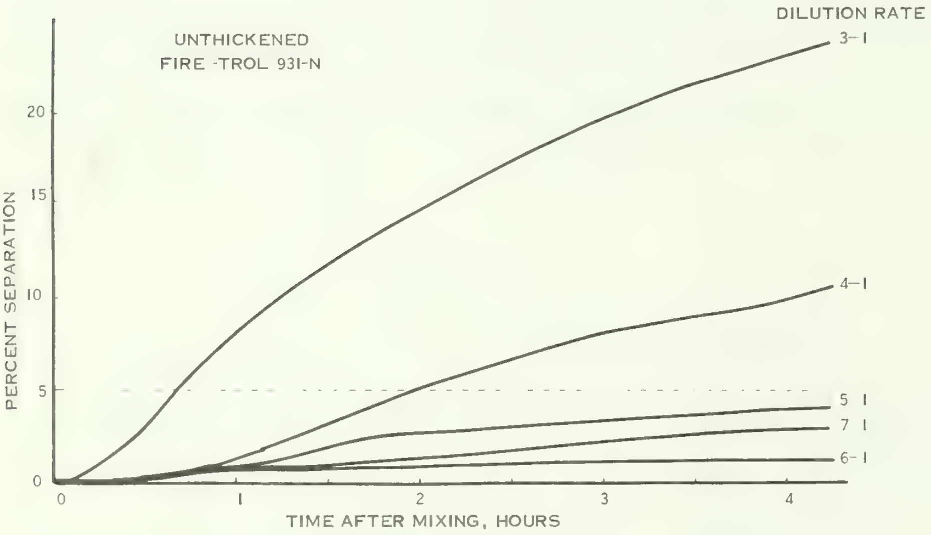

Figure 11.--Separation of unthickened Fire-Trol 931-N as a function of time after mixing.

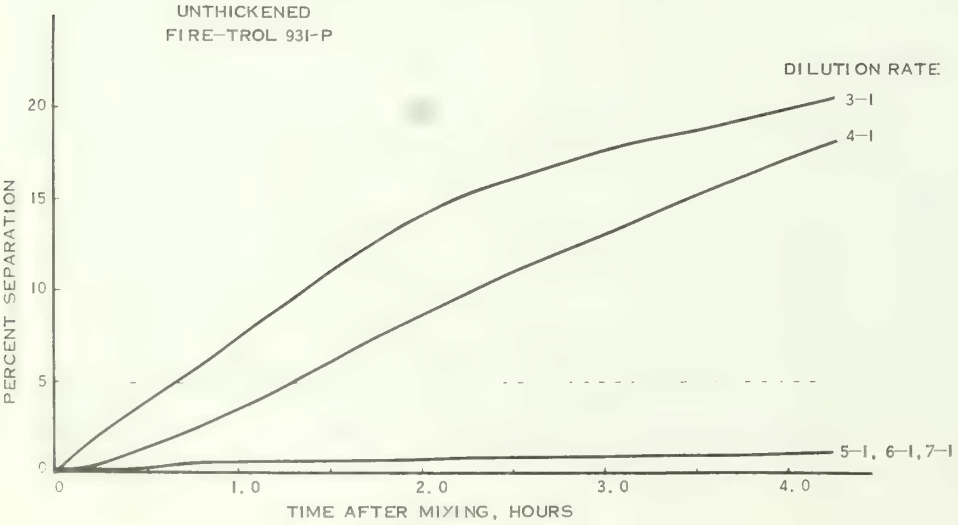

Figure 12.--Separation of unthickened Fire-Trol 931-P as a function of time after mixing.

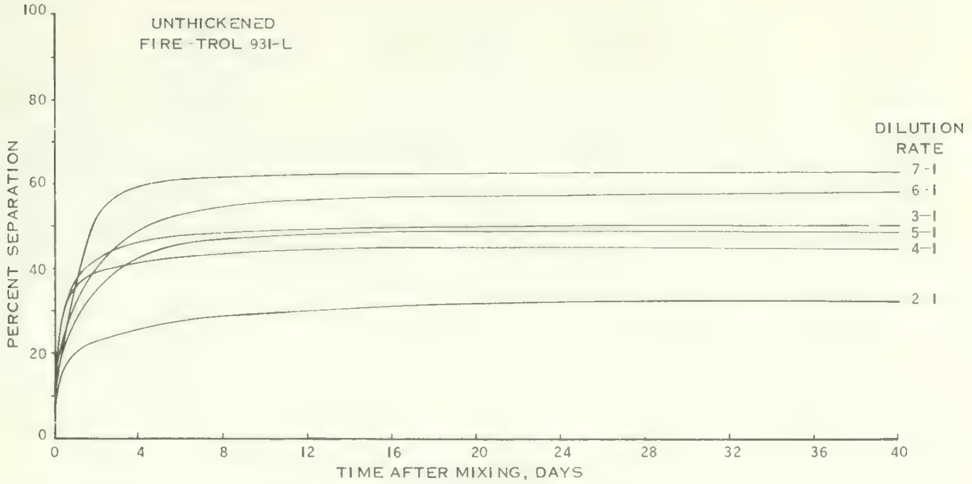

Figure 13.--Long-term separation of unthickened Fire-Trol 931-L as a function of time after mixing.

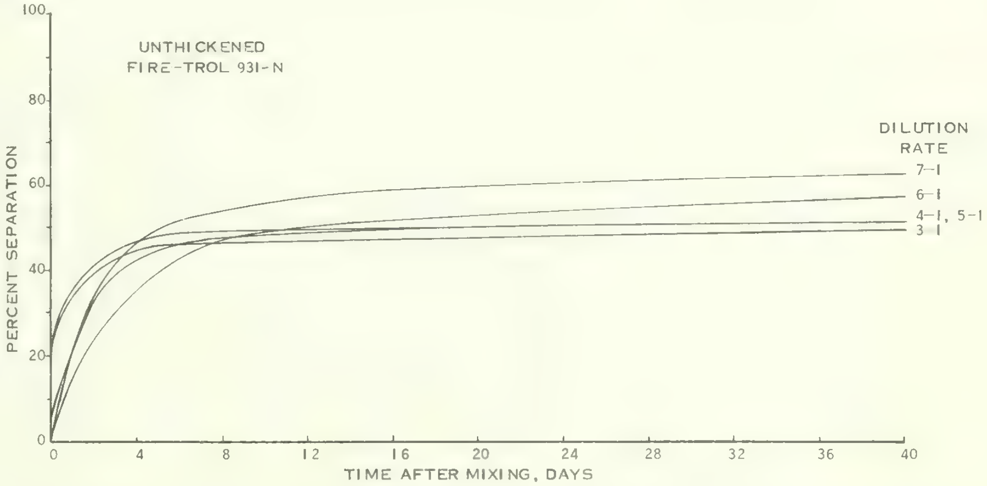

Figure 14.--Long-term separation of unthickened Fire-Trol 931-N as a function of time after mixing.

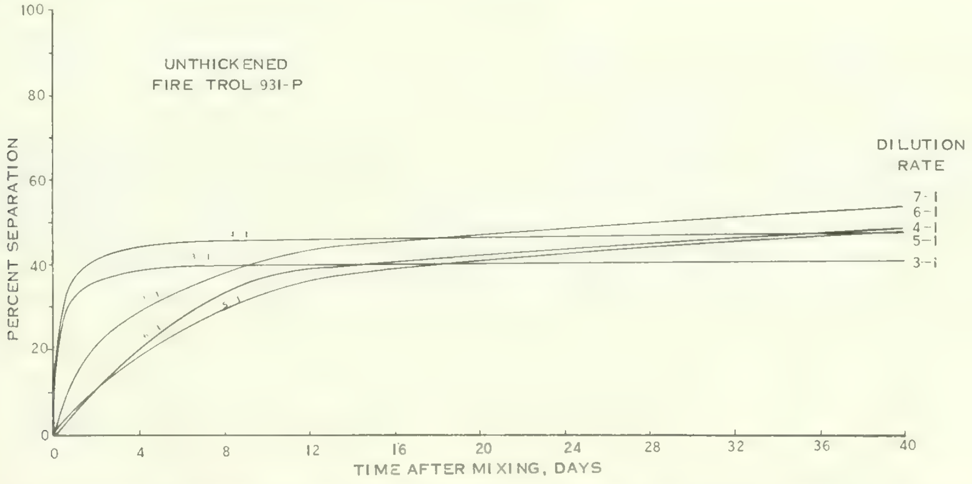

Figure 15.--Long-term separation of unthickened Fire-Trol 931-P as a function of time after mixing.

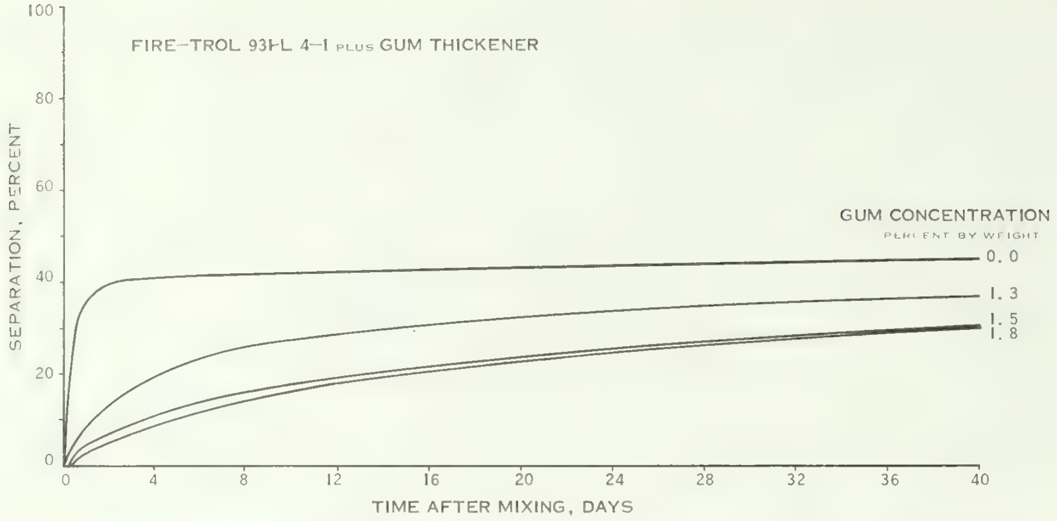

Figure 16.--Separation of gum-thickened Fire-Trol 931-L as a function of time after mixing.

Separation occurring at various time intervals for the several formulations is given below:

Dilution rate	*Time following mixing*	*Percent separation (by volume)*		
		Fire-Trol 931-L	*Fire-Trol 931-N*	*Fire-Trol 931-P*
4:1	1 h	11	10	3
	[11] 4 h	25	23	17
	1 d	38	32	39
	7 d	48	50	46
	14 d	52	51	46
		1.5 percent gum-thickened Fire-Trol 931-L		
4:1	4 h		0	
	1 d		5	
	7 d		16	
	14 d		20	
	30 d		30	

The only gum-thickened formulation evaluation for separation was Fire-Trol 931-L diluted at 4:1 with several concentrations of gum thickener. At all gum concentrations separation occurred gradually, reaching 20 percent after 2 weeks and approximately 30 percent after 1 month (fig. 16). It is interesting to note that separation occurred to a greater extent than would be expected on the basis of the solution's viscosity (Viscosity section 3.1.3., figures 3-6). Therefore, diluted 931-L, with or without thickener, does not fulfill the requirements for separation.

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[11] Required performance at 4 hours is ≤5 percent separation (by volume).

Spoilage (3.1.13.)

Requirements: One gallon of liquid concentrate will be placed in four 1-quart jars. A 25 cc specimen from a culture of aerobacter bacteria will be added to two of the samples without stirring or agitation. The four samples will be stored unsealed (loosely covered) under ambient conditions at 75-85° F. The samples will be visually checked and the viscosity measured at weekly intervals for a 3-month period. Separation of more than 5 percent, or a decrease in viscosity, constitutes spoilage. Growth of mold or an unpleasant odor is also considered spoilage.

Performance: Samples of unthickened Fire-Trol 931-L, 931-N, and 931-P were diluted at 3:1, 4:1, 5:1, 6:1, and 7:1, and insulted with bacteria. These were visually inspected for growth of mold and rate of separation. Because of the naturally occurring separation, it was not meaningful to determine the viscosity weekly--since this would require agitation of the sample and the insult bacteria. Fire-Trol 931-L, 931-N, and 931-P took about 1 1/2 months before spoilage was evident to an extent that the materials would not meet the requirements. The 3:1 dilutions of Fire-Trol 931-N were the first samples to show mold growth and give off a pungent odor.

Samples of gum-thickened Fire-Trol 931-L were similarly insulted with a bacteria. All gum-thickened samples promoted mold growth, with an increasing separation rate. Spoilage began at irregular initiation periods, as early as 3 days after being insulted. The initiation period for spoilage probably depends on the number of bacteria in the insult, which could not be controlled, as well as many other factors. Although there is no specification for thickened liquid base retardants, operational use is not recommended for a material having these spoilage characteristics and thus viscosity degradation.

The San Dimas Equipment Development Center tested for spoilage (data on file at the Northern Forest Fire Laboratory and San Dimas Equipment Development Center), with Fire-Trol 931-N and 931-P concentrates and 4:1 mixtures. Both solutions of each formula supported the bacterial culture, as evidenced by an unpleasant odor and mold growth where the culture was at the surface of the liquid. However, the culture did not degrade either the concentrate or the "mixed retardant."

Pumpability (3.1.14.)

Requirements: For retardants with non-Newtonian flow characteristics, an electric pump (flow model Mac X-3, 220 volt, 3 phase, 3/4 horsepower, 2,580-3,450 r/min) with a 1-inch inlet and outlet and a cast iron impeller will be used. The pump will be run at 3,400 r/min to transfer liquid concentrate from a holding tank to a weighing tank. Standard procedures will be used to monitor the pump r/min and the weight of retardant in the weighing tank. These procedures will be performed five times for each different sample. The rate of weight increase and the specific weight of the retardant will be used to determine the flow rate in gallons per minute. A minimum flow rate of 12 gal/min must be obtained.

For retardants with Newtonian flow characteristics, the kinematic viscosity for the material will be computed using density and viscosity:

$$\frac{\text{viscosity (cP)}}{\text{density } \left(\frac{\text{g}}{\text{cm}^3}\right)} = \text{centistokes}$$

The retardant shall not exceed 1,800 centistokes.

Performance: The tests, performed by the San Dimas Equipment Development Center (Pickett 1975), showed that Fire-Trol 931-L concentrate meets performance requirements (data on file at San Dimas Equipment Development Center and Northern Forest Fire Laboratory). Because some components separated, two separate centistoke tests were conducted. Material from the bottom of the barrel was calculated at 3,015 and 3,103 centistokes, and material from the top of the barrel at 1,055 centistokes. (The maximum acceptable level is 1,800.)

On four test runs the 931-L concentrate was pumped in excess of 12 gal/min (the minimum allowable) and in one test at 9.5 gal/min. The average, 13.4 gal/min, was considered acceptable. It was noted during the tests that the pump could not be primed with the Fire-Trol 931-L concentrate.

In pumpability tests Fire-Trol 931-N had an average flow rate of 9.1 gal/min and a maximum of 10.3 gal/min, both below the required 12 gal/min. Therefore, pumpability of the retardant is unacceptable.

Fire-Trol 931-P could not be pumped because of crystals formed when the concentrate salted out. (The retardant had a 0.6 percent decrease in salt content because of the "salting out.") SDEDC recommends disqualifying 931-P because of the possible serious abrasion to pumps or other hardware used at air tanker bases.

Air Drop Characteristics (3.1.15.)

Requirements: For aircraft-applied-type retardant the liquid concentrate will be mixed at the manufacturer's recommended level and dropped from a TBM-type air tanker. The air tanker will have a tank and gating system with two gates, each being 9 by 136 inches. Aircraft speeds will be held at 105-115 knots, temperature 60-90° F, relative humidity 20-60 percent, and <5 mi/h wind. For a load of 600 gallons dropped from 200 (±20) feet and with a wind of 5 mi/h or less:

1. 60 percent (400 gallons) or more of the retardant shall fall within the total pattern area.

2. The area covered by ≥ 2 gal/100 ft^2 must be $\geq 4{,}000$ ft^2.

3. The 2 gallons per 100-ft^2 area must have a continuous length of >150 ft.

Performance: Because the drop performance of unthickened Fire-Trol 931-D had previously been quantified under the conditions that are specified for this evaluation, and because insignificant differences exist in the drop characteristics of Fire-Trol 931-D and other similarly formulated Fire-Trol 931 products (containing 10-34-0, attapulgite clay, coloring, and corrosion inhibitors, and diluted 4:1; i.e., Fire-Trol 931-L, 931-N, 931-P), the performance data were taken from previous drop tests at Porterville, California. These tests were reported in "An evaluation of the drop characteristics and ground distribution patterns of forest fire retardant" (George and Blakely 1973).

In that analysis, performance models were developed based on the actual drop data, which predicted retardant recovery and area of coverage by concentration class. Fireline length at the 2 gal/100 ft^2 coverage level was given for each drop. Utilizing these data, the performance of Fire-Trol 931-D at the conditions specified under requirements is given below:

Requirement	*Performance of Fire-Trol 931-D*
Recovery: 60 percent of total load or 400 gal	550 gal at 0 mi/h wind 427 gal at 5 mi/h wind
Area of coverage at ≥2 gal/100 ft^2 ≥4,000 ft^2	9,264 ft^2 at 0 mi/h wind 4,802 ft^2 at 5 mi/h wind
Length of fireline ≥2 gal/100 ft^2 >150 ft	∿208 ft[12]

Note that the predictions for water dropped under the same conditions also meet all the requirements listed above.

In late 1973, gum-thickened and petrolite-thickened Fire-Trol 931-L were submitted to the Forest Service (NFFL) for evaluation. In January 1974, cooperative agreements were made between the USDA Forest Service (Northern Forest Fire Laboratory) and Chemonics Industries to perform laboratory tests and actual drop tests with the two formulations. This study was initiated in February 1974, at Marana, Arizona. A B-17 was selected as the test aircraft rather than the TBM as specified in the requirements for two reasons:

1. The TBM was dropped from operational use as an approved air tanker in 1974.

2. Previous tests, investigating the effect of retardant rheological properties on drop characteristics, had been conducted using the B-17 (Intermountain B-17, No. 71) and provided a data base for these tests--thus reducing the number of required drops.

During these tests, 44 drops of 466 gallons each (1 compartment) were made and the ground distribution patterns analyzed.[13]

Preliminary analysis of these data has been completed and the following conclusions drawn:

1. The drop performance of the unthickened Fire-Trol 931-L is vastly improved by the addition of the gum-thickening agent or the Petrolite inverter. The gum-thickened retardant, however, is superior to the Petrolite emulsion and has the advantage that the concentration of the gum can be controlled to allow selection of a much wider range of retardant rheological properties.

2. The optimum viscosity of the gum-thickened retardant appears to be near 2,000 centipoise. At higher viscosities (3,000 cP) the areas of coverage tended to be reduced (especially at the lower drop heights). At higher drop heights (greater than 300 ft) and coverage levels (3 or 4 gal/100 ft^2), however, there may be advantages for APP solutions having viscosities near 3,000 centipoise.

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[12] Determined as an average of all drops from 200 ft or less and with ≤5 mi/h winds (total number of drops = 10, Sd = 25 ft, Sm = 8 ft).

[13] George, C. W. 1974. Evaluation of the drop characteristics of two thickened liquid concentrate fire retardant systems, INT Study Plan 2107-17G, Intermt. For. and Range Exp. Stn., Ogden, Utah.

The differences between unthickened and gum-thickened retardant and also the effects of the gum-thickened retardant viscosity can be determined by comparing the areas of ≥ 2 gal/100 ft^2 coverage in figure 17. Similar conclusions can be drawn from other ground distribution pattern parameters (such as retardant recovery and fireline lengths--figure 18).

Further analysis will be required to correlate levels of performance using the B-17 as a delivery platform, with the requirements specified using the TBM. It can be assumed, however, that the gum-thickened and Petrolite-thickened retardants greatly exceed the performance levels required (based on performance comparisons between unthickened Fire-Trol 931-L and other retardants dropped from TBM and B-17 air tankers).

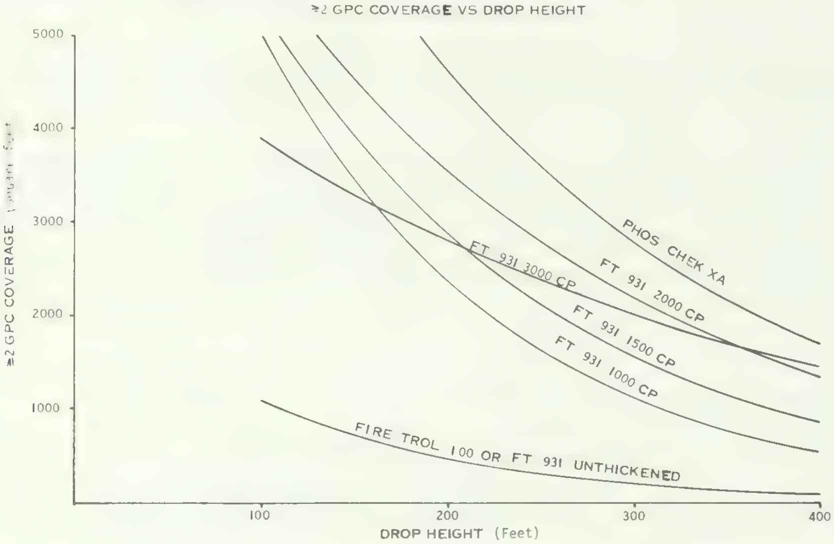

Figure 17.--Comparison of the area of coverage at 2 gal/100 ft^2 for drops of several viscosities of gum-thickened Fire-Trol 931-L, unthickened Fire-Trol 931-L, Fire-Trol 100, and Phos-Chek XA, as a function of drop height.

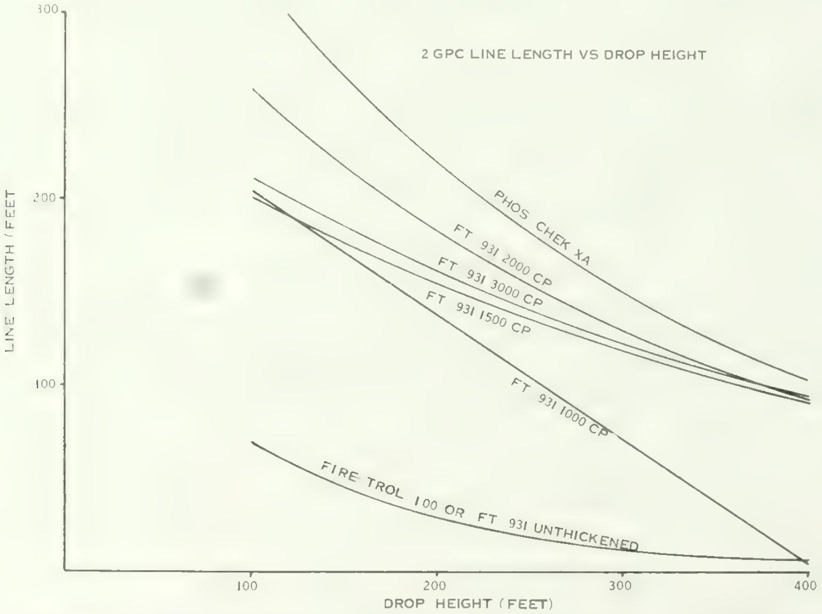

Figure 18.--Comparison of the length of fireline ≥ 2 gal/100 ft^2 for drops of several viscosities of gum-thickened Fire-Trol 931-L, unthickened Fire-Trol 931-L, Fire-Trol 100, and Phos-Chek XA, as a function of drop height.

DISCUSSION

Several Fire-Trol 931 APP formulations (appendix A) were submitted for screening and testing by Chemonics Industries. Although preliminary tests have been performed on a number of these formulations, primary emphasis in this report has been placed on the performance of Fire-Trol 931-L, 931-N, and 931-P, gum-thickened solutions of Fire-Trol 931, and Petrolite emulsions of Fire-Trol 931. A number of dilutions of each of the concentrations were tested because of the flexibility to tailor the retardant solution to specific needs--independent selection of salt content and viscosity. The series of tests were conducted as closely as possible to procedures outlined in USDA Interim Specifications 5100-00301 and 5100-00302a. The formulations discussed were primarily designed for air application and were evaluated accordingly.

It has been stated and emphasized in this report that there is no current specification for thickened liquid-type fire retardants and that some of the requirements may not be totally appropriate. All of the specified tests were conducted, plus several additional tests; however, a number of test procedures required modification to suit specific situations which were primarily dictated by the characteristics of the individual formulations.

Three general areas warrant discussion beyond that given in the specific test sections: corrosion, stability of the mixed retardant, and retardant drop characteristics.

Corrosion. Fire-Trol 931-L, 931-N, and 931-P formulations, when mixed for use within the dilution rates tested, met the performance required in the specifications (<1 mil/yr on Al-2024-T3) for uniform corrosion. However, Forest Service specifications do not require inhibition of corrosion to common alloys other than aluminum 2024-T3 and do not consider type of corrosion other than uniform corrosion, intergranular corrosion, and pitting tendency (for example, types of corrosion such as crevice, galvanic, and fatigue corrosion are not considered).

A summary of field surveys and laboratory studies conducted by Ocean City Research Corporation (OCRC) (Gehring 1974) indicates that corrosion performance requirements should be broadened to include several other alloys, additional types of corrosion, and specific corrosion tests which will better evaluate corrosion effects. In specific tests quantifying the corrosiveness of Fire-Trol 931-L, OCRC came to several conclusions (appendix B):

1. Fire-Trol 931-L is only mildly corrosive to aluminum alloys (≈1 mil/yr by alternate immersion tests).

2. Fire-Trol 931-L is severely corrosive to magnesium and zinc alloys. Fire-Trol 931-L corrodes zinc, magnesium, and galvanized steel at significant rates (>5 mils/yr by alternate immersion tests). Thus, contact of galvanized control cables or magnesium alloys with Fire-Trol 931-L should be avoided.

3. The corrosion inhibitor system in Fire-Trol 931-L does not completely eliminate susceptibility to stress corrosion.

4. The corrosivity of Fire-Trol 931-L can be significantly reduced by the use of additional inhibitors.

Several other conclusions regarding other formulations or basic liquid systems are of interest.

1. Fire-Trol 931-D (sodium dichromate inhibitor) corrodes 2024-T3 aluminum, zinc, and magnesium at significant rates (>5 mils/yr by total immersion tests).

2. Uninhibited ammonium polyphosphate (8.3 percent P_2O_5 equivalent) should never be used as a fire retardant without effective corrosion inhibitor additives.

3. Galvanic corrosion can occur at significant rates (∿3 mils/yr) with the use of all inhibited formulations.

4. Pyro (11-37-0) causes severe corrosion on almost all alloys (except stainless steel). Pyro should never be used without corrosion inhibitor additives or coatings.

Although the sodium ferrocyanide corrosion inhibitor in Fire-Trol 931-L, 931-N, and 931-P very significantly reduced the corrosion rate of exposed Al-2024-T3 as compared to the sodium dichromate contained in Fire-Trol 931-D, the sodium ferrocyanide may have undesirable staining effects. The sodium ferrocyanide provides corrosion protection by building up a heavy blue coating on the metal surface. The degree of bluing depends on the type of metal, its surface characteristics, etc. This coloring can be quite difficult to remove. Staining of other surfaces such as concrete ramps, etc., can be expected.[14] This coloring may or may not be a problem depending on specific situations.

Solution Stability. There has been considerable discussion concerning the requirements for stability of mixed retardant, especially a demand-mixed Fire-Trol 931-L. The storage requirement for an unthickened mixed retardant is a 4-hour stability period (separation <5 percent at the end of 4 hours), while for a thickened mixed retardant the solution must maintain stability for a 1-year period. Unthickened Fire-Trol 931 products separate to about 50 percent in less than 4 days depending on conditions (10-25 percent in 4 hours). As formulated with the attapulgite clay and iron oxide, it is likely that significant changes in the formulation would be required to meet present specifications.

The gum-thickened Fire-Trol 931 formulations, although their stability is greatly improved over the unthickened formulations, still undergo significant change following mixing (in terms of both viscosity and separation). A possible way these formulations might be formulated to circumvent this problem is by including the coloring agent in the gum thickener and removal of the clay from the liquid APP solution entirely (since its only purpose is to stabilize or hold the color in suspension). A related problem, however, primarily dependent on the quality and control of the gum and APP characteristics, is the sensitivity of the various ingredients. Data presented in the sections on Viscosity (3.1.3.) indicate that the quality of the gum (storage time is a consideration as well as gum separation since the gum settles within the carrier) and the salt content of the retardant (mixing rates) greatly influence the resulting viscosity and solution stability. Only with very precise control of these variables (including adequate circulation of both the liquid gum and the APP solution) can the properties of the end product be controlled (resulting in a mixed retardant with tailored properties). The experiences at the Boise Air Attack base with the gum-thickened Fire-Trol 931-P system have verified the preceding statements. To date the hardware and formulations have not demonstrated that control of retardant properties has been achieved to the necessary degree (salt content ±10 percent, and viscosity ±200 centipoise).

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[14] Sodium carbonate (baking soda) has been used to effectively clean stained concrete pads. From communication with Kathy Lacey of Chemonics Industries.

If retardants were delivered immediately after being loaded into the aircraft, there would be little if any problem with separation. However, in actuality, this does not always occur. A survey of air tankers in six different Forest Service Regions (August 1974) indicated 59 percent of the 73 aircraft surveyed at 47 bases always sit loaded, 43 percent sit loaded occasionally, and only 5 percent never sit loaded. It is questionable whether sitting loaded should be required in any case; however it is a current practice and occurs very frequently during periods of high fire danger.

The type of exposure prevalent to air tankers in the field indicates corrosion and retardant solution requirements are important. As earlier discussed, 25-50 percent separation can occur in a matter of hours or days. If this separation exists at the time a drop is made, it is predicted that 50 percent or greater of the effective portion of the drop will be uncolored. This presents definite problems where tactics require multiple drops be tied together (from more than one aircraft or multiple drop increments from the same aircraft). Figure 19 shows the predicted drop pattern from an entire drop and from portions of the drop, with and without color. These predictions are based on the flow rate for a 500-gallon drop from a B-17 using the flow rate-ground distribution model developed by Honeywell (Swanson and Helvig 1973). Thus, it would be highly desirable to have a stable retardant solution with the color uniformly distributed throughout. Similarly, based on current practices, it is desirable and not unreasonable to have retardant solutions that maintain stability (color and viscosity) after being mixed, for a period of at least 2 weeks and preferably a month. Air tankers occasionally sitting loaded, if not the intention or a legitimate requirement, will likely always be a reality.

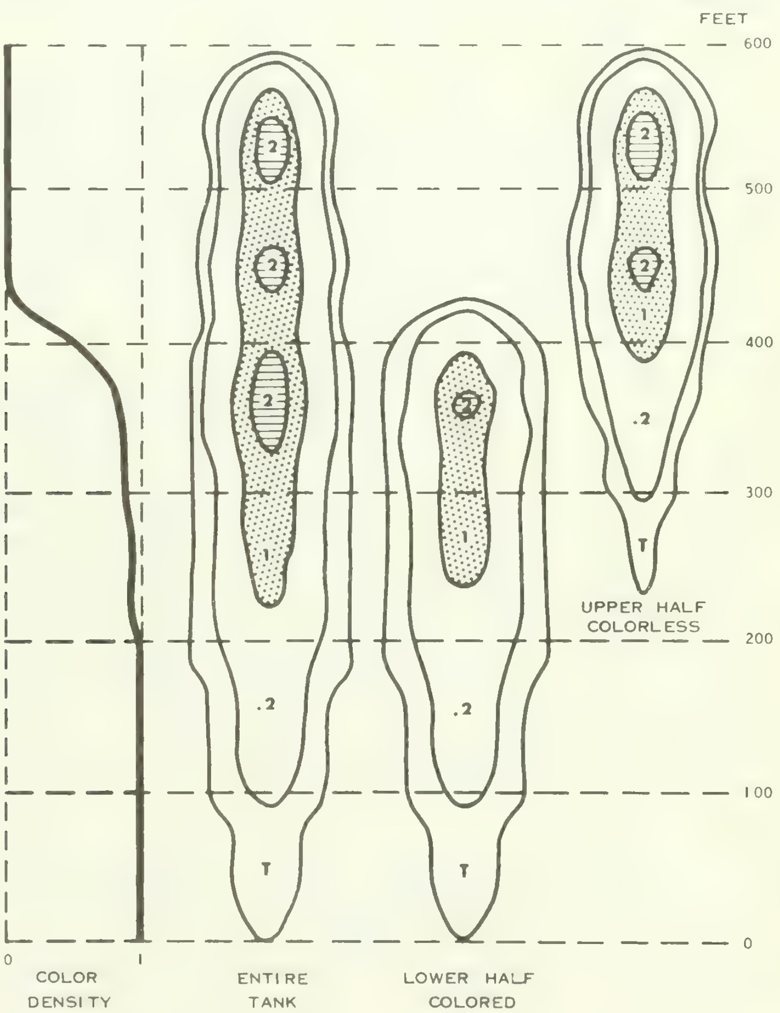

Figure 19.--The effect of retardant color separation as shown by predictions of the ground distribution patterns and color distribution of 500 gallons of retardant dropped from a B-17.

Retardant Drop Characteristics. Present specifications contain drop requirements which can be satisfied by water containing no additives. Early specifications recognized that the drop characteristics of retardants were important considerations in product qualification. However, practical standards had not been identified because thorough studies quantifying these parameters had not been conducted (a number of rather qualitative studies had been undertaken). Since these specifications were first prepared (1969) a number of drop studies have been conducted and practical requirements are now possible.

The drop data as outlined in Section 3.1.15. (Air Drop Characteristics) well illustrate differences in deliverability that result from varying retardant physical-chemical or rheological properties. Extreme differences in retardant deformation, breakup, and resulting ground distribution patterns exist between the unthickened Fire-Trol 931 and the gum-thickened Fire-Trol 931 (fig. 17 and 18). The effects of wind, aircraft speed, drop height, retardant flow rate, and load size are much less pronounced on the gum-thickened retardant than on the unthickened retardant. An explanation of these phenomena is probably best given by Andersen and others (1974a).

Thus, the use of gum-thickened retardants, tailored to specific drop and fire situations, can allow effective drops to be made from higher and safer drop heights (fig. 20)[15] than considered before. Of course, there are trade-offs between accuracy and drop height which are affected by the wind conditions and type of attack (direct and indirect), but limitations will likely be determined through experience and will be subject to human abilities.

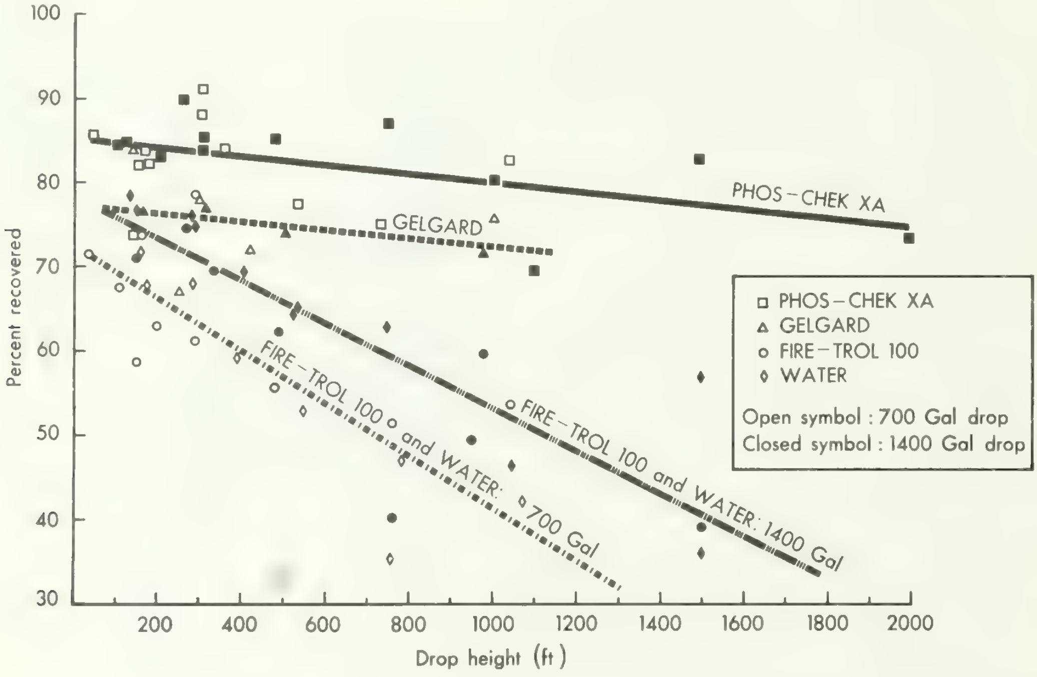

Figure 20.--The effect of type of retardant and drop height on the percent of total retardant reaching the ground.

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[15] Review of over 50 air tanker accidents reported to the National Transportation Safety Board during the period 1964 to 1974 indicates 55 percent of the fatalities (a total of 31 fatalities during this 11-year period) occurred from accidents during drop maneuvers. "Improving aerial delivery of chemicals through research" paper presented by C. W. George, 10-24-74, at the California-Nevada Forest Fire Council.

RECOMMENDATIONS

Based on the results of this evaluation and other studies being conducted in the area of retardant research, several recommendations regarding the use and formulation of Fire-Trol 931 APP have been made:

1. The Fire-Trol liquid ammonium polyphosphate fire retardants tested here do not meet all the specification requirements and therefore should not be used operationally in their present forms.

2. Emphasis should be placed on developing corrosion inhibitor systems for Fire-Trol 931 APP solutions which will provide corrosion protection for those alloys frequently encountered in addition to aluminum 2024-T3 and for types of corrosion encountered other than uniform and intergranular.

3. Research and development should be undertaken to improve retardant solution stability (viscosity and separation)--this may include a substitute for attapulgite clay in the liquid concentrate.

4. Gum-type thickening agents should be developed which are stable in storage (not requiring frequent circulation) and relatively insensitive to the type of APP solution, salt concentration, pH, water temperature, etc., or are otherwise adequately controllable.

5. Only those basic types of ammonium polyphosphate (10-34-0) solutions which have similar properties should be used. Use of various APP solutions resulting in different physical-chemical characteristics (corrosion, viscosity, etc.) can be adjusted for operationally only with considerable effort and supportive calibration data.

6. Mixing and handling hardware should be developed which will allow precise selections of the final retardant properties (viscosity, salt content, color) within a broad range.

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APPENDIX A

COMPOSITION OF FIRE-TROL APP FORMULATIONS

COMPOSITION OF FIRE-TROL AMMONIUM POLYPHOSPHATE PRODUCTS

Product Identification	Composition	Percent in Concentrate
Fire-Trol 934	Allied 10-34-0	96.2
	Sodium Dichromate	
	Surfactant	
Fire-Trol 930	Allied 10-34-0	98.5
	Sodium Dichromate	
Fire-Trol 931-A	Allied 10-34-0	94.1
	Attapulgite Clay	
	Fe_2O_3	
	$MgCl_2 \cdot 6H_2O$	
Fire-Trol 931-B	Allied 10-34-0	88.3
	Attapulgite Clay	
	Fe_2O_3	
	Allied Inhibitor	
Fire-Trol 931-C	Allied 10-34-0	93.5
	Attapulgite Clay	
	Fe_2O_3	
	Sodium Dichromate	
Fire-Trol 931-D	Allied 10-34-0	93.5
	Attapulgite Clay	
	Fe_2O_3	
	Sodium Dichromate	
Fire-Trol 931-E	Cominco 10-34-0	92.5
	Attapulgite Clay	
	Fe_2O_3	
	Sodium Dichromate	
Fire-Trol 931-F	Stauffer 10-34-0	93.5
	Attapulgite Clay	
	Fe_2O_3	
	Sodium Dichromate	
Fire-Trol 931-G	TVA 10-34-0	93.5
	Attapulgite Clay	
	Fe_2O_3	
	Sodium Thiosulfate	
	Sodium Molybdate	
	2-mercaptobenzothiazole	

Fire-Trol 931-J	Allied 10-34-0 Attapulgite Clay Fe_2O_3 Sodium Thiosulfate Sodium Molybdate 2-mercaptobenzothiazole	92.8
Fire-Trol 931-K	Cominco 10-34-0 Attapulgite Clay Fe_2O_3 Sodium Thiosulfate Sodium Molybdate 2-mercaptobenzothiazole	92.8
Fire-Trol 931-L	Allied 10-34-0 Attapulgite Clay Fe_2O_3 Dye Sodium Ferrocyanide[1]	92.9
Fire-Trol 934-L	Allied 10-34-0 Sodium Ferrocyanide	98.5
Fire-Trol 931-M	Stauffer 10-34-0 Attapulgite Clay Fe_2O_3 Dye Sodium Ferrocyanide	93.0
Fire-Trol 931-N	Cominco 10-34-0 Attapulgite Clay Fe_2O_3 Dye Sodium Ferrocyanide	93.0
Fire-Trol 931-P	Simplot 10-34-0 Attapulgite Clay Fe_2O_3 Dye Sodium Ferrocyanide	93.0
Gum-thickened Fire-Trol 931	931-L formulation Gum-thickener	97.5-99.0
Invert emulsion thickened Fire-Trol 931	931-L formulation Petrolite invert emulsifier	95-97

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[1] Patent pending for use in Ammonium Polyphosphate Fire Retardant.

APPENDIX B

RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

From

Investigation of Retardant Caused Corrosion
Final Report
Ocean City Research Corporation
USDA Forest Service Contract #26-3250, 1974

I. ABSTRACT

A program was undertaken to assess the severity of fire retardant caused corrosion on air tankers and mixing plants. A representative number of air tankers and mixing plants were inspected and comprehensive laboratory tests were conducted to identify and quantify the extent of different types of corrosion. In the laboratory tests, five fire retardants and ten alloys were investigated. The laboratory tests also included evaluation of ten protective coatings for use as maintenance coatings and evaluation of different chemicals for use as corrosion inhibitors in retardant solutions. The results of the investigation are presented with recommendations for control of fire retardant corrosion.

II. CONCLUSIONS

A. The aerial fire retardants currently used to suppress forest fires corrode aircraft and ground mixing equipment.

B. Corrosion of aircraft and ground mixing equipment continues to create maintenance problems.

C. The corrosivity of fire retardants is not consistent; corrosion rates vary for each alloy depending on the particular retardant formulation.

D. Phos-Chek XA, Fire-Trol 100, and Phos-Chek 259 are relatively non-corrosive to aluminum alloys (≈.1 mil/yr by alternate immersion test).

E. Fire-Trol 931-L is only mildly corrosive to aluminum alloys (≈1 mil/yr by alternate immersion test).

F. Fire-Trol 931-D corrodes 2024-T3 aluminum, zinc, and magnesium at significant rates (>5 mil/yr by total immersion test).

G. Fire-Trol 931-L corrodes zinc and magnesium at significant rates (>5 mil/yr by alternate immersion test).

H. In laboratory tests, Fire-Trol 100 corrodes brass and magnesium at significant rates (>3 mil/yr by alternate immersion test). Field surveys also showed that Fire-Trol 100 corrodes steel significantly which is contrary to the results of laboratory tests.

I. Phos-Chek 259 corrodes brass and zinc at significant rates (>5 mil/yr by alternate immersion test).

J. Overall, Phos-Chek XA is the least corrosive of the fire retardants. It does not cause significant corrosion on any of the alloys commonly found on air tankers or in ground mixing plants.

K. Almost all alloys will corrode excessively in uninhibited diammonium phosphate (15.0 percent solution, by weight), uninhibited ammonium sulfate (15.0 percent solution, by weight), and uninhibited ammonium polyphosphate (8.3 percent solution, P_2O_5 equivalent by weight). These chemicals should never be used as fire retardants without effective corrosion inhibitor additives.

L. Alternate immersion conditions are significantly more corrosive to naval brass than total immersion conditions.

M. Stainless steel alloys are virtually immune to general corrosion caused by fire retardants.

N. Galvanic corrosion can occur at significant rates (3 mil/yr) even with the use of corrosion-inhibited retardants.

O. The addition of corrosion inhibitors to retardant formulas can effectively reduce corrosion.

P. Fire retardants without corrosion inhibitors are conducive to both stress corrosion and corrosion fatigue. The corrosion inhibited formulations currently in use do not completely eliminate susceptibility to stress corrosion.

Q. The corrosivity of fire retardants can be significantly reduced by the use of additional inhibitors. Further work as follows is required to identify the most effective inhibitors:

1. Inhibitor duration tests
2. Stress corrosion cracking tests
3. Corrosion rate versus inhibitor concentration tests
4. Corrosion rate versus dilution tests
5. Corrosion fatigue tests
6. Inhibitor combination tests

R. Fire retardants rapidly deteriorate many of the common maintenance coatings. Certain epoxy-base coatings will provide adequate protection as maintenance coatings.

S. The current interim USFS specification is realistic in limiting the maximum allowable corrosion rate of 1 mil/yr on 2024-T3 aluminum. However, the specification should be expanded to include other alloys, and other types of corrosion test. Also, the test procedure should be modified to account for corrosion rate - time effects and differences that might occur under conditions of alternate immersion.

III. RECOMMENDATIONS TO CONTROL FIRE RETARDANT CORROSION

A. Uninhibited fire retardants are quite corrosive to almost all alloys. Use only those retardant formulations containing effective corrosion inhibitor additives.

B. Pyro causes severe corrosion on almost all alloys (except stainless steels). Pyro should never be used as a fire retardant without corrosion inhibitor additives.

C. Most of the inhibited fire retardant now used across the country corrode aluminum alloys at an insignificant rate. However, other alloys commonly used on air tankers are susceptible to appreciable corrosion caused by exposure to fire retardant. Therefore, continuing preventative maintenance is required to control corrosion. Normal maintenance procedures as established by the Federal Aviation Administration (Advisory Circular No. 43-4 dated 5-15-73) should be followed.

D. Fire retardants are conducive to galvanic corrosion. Where possible, avoid the following galvanic couples:

1. Aluminum alloys coupled to either copper-base alloys or stainless steel alloys.
2. Carbon or low alloy steels coupled to either copper-base alloys or stainless steel alloys.
3. Galvanized steel coupled to aluminum, steel, copper or stainless steel alloys.

E. Fire retardants corrode mild steel alloys sufficient to cause seizing of threaded fasteners, hinges, etc. Where seizing is a problem, substitute an austenitic Type 304 stainless steel.

F. Fire-Trol 100 and Fire-Trol 931-L are severely corrosive to magnesium alloys. In general, avoid the use of magnesium alloys on air tankers, take particular care to prevent either of the above-mentioned retardants from contacting magnesium alloys for any appreciable time.

G. Fire-Trol 931-L is corrosive to galvanized steel. On air tankers, do not allow Fire-Trol 931-L to contact galvanized control cables for any appreciable period of time.

H. Vapors given off by some of the aerial fire retardants appear to be significantly corrosive. Avoid entrapment of fire retardant vapor in air tankers and storage tanks by providing proper ventilation.

I. Fire retardants rapidly degrade most organic maintenance coatings. In mixing plant service, use amine-cured epoxy coatings for general exterior maintenance. For coating the interior of steel storage tanks, use a high build coal tar epoxy coating.

IV. RECOMMENDATIONS FOR FOREST SERVICE ACTION

A. Initiate further studies in the following areas:

1. Corrosion Inhibitors
2. Vapor Zone Corrosion
3. Corrosivity Variation of Liquid Ammonium Polyphosphate
4. Corrosion Rate Versus Viscosity.

B. Initiate steps to effectively transfer the technology developed in this program for implementation by air operators and retardant suppliers.

C. Consider the acquisition of more sophisticated instrumentation that would enable more accurate determination of corrosion rates by electrochemical polarization methods.

D. Revise and expand USFS interim specification 5100-00301 and 5100-00302a to reflect the technology developed in this program. Specific items include:

1. Expand the corrosion testing to include determination of general corrosion rates not only on 2024-T3 aluminum but also 7075-T6 aluminum, naval brass, 4130 steel, and magnesium.

2. Determine corrosion rates under both total immersion conditions and alternate immersion conditions.

3. Conduct the total immersion tests over at least 30 days. Determine corrosion rates by polarization measurements on the 1st, 3rd, 7th, 14th, and 30th day in test. In addition, weigh each test specimen prior to and after the test to allow determination of corrosion rate by weight loss.

4. Conduct the alternate immersion tests over 30 days. Determine general corrosion rates by weight loss measurements.

5. Substitute double cantilever beam (DCB) type specimens for the U-bend specimens now specified to check for susceptibility to stress corrosion cracking. Include 2024-T3 aluminum and 7075-T6 aluminum in the SCC tests. The test should be total immersion for 30 days.

E. Consider modifying existing specifications on fire retardants so that corrosion inhibitor additives can be specified for different retardant solutions instead of qualifying proprietary formulas.

General Corrosion Rates (mils/yr)

Determined by Weight Loss Measurements

		304 SS	410 SS	BRASS	2024 Al	2024 AlC	6061 Al	7075 Al	4130 STEEL	ZINC	MAG
TOTAL IMMERSION TEST (2 MONTHS)											
Fire-Trol 931-D		.0096	.0054	.1743	7.113	1.857	.1530	2.108	.0898	23.29	>100.0
ALTERNATE IMMERSION TEST (6 MONTHS)											
Fire-Trol 931-L		.0026	.0097	.7800	1.363	.5419	.5038	.7664	.2563	6.383	>100.0
DETERMINED BY LINEAR POLARIZATION MEASUREMENTS OVER A PERIOD OF 2 MONTHS											
Fire-Trol 931-D	Initial	.0081	.1663	.1665	.1068	.1828	.1026	.0749	.0266	>100	347.8
		.0069	.1101	.1080	4.986	1.763	.8014	.8565	.0456	18.65	
		.0051	.0748	.1865	5.488	1.325	.9788	1.031	.0140	2.283	
		.0031	.0058	.1163	4.333	.6640	.7945	.9794	.0195	1.197	
		.0010	.0014	.1108	3.080	.5517	.7822	.6659		.6921	
	Final	.0064	.0043	.0871	2.263	.7676	.7377	.9389			
	Average	.0051	.0605	.1292	3.376	.6757	.6995	.7578	.0264	14.75	>100

THE FIVE WORST GALVANIC CORROSION RATES FOR FIRE TROL 931

	CATHODE	E_c VOLTS	ANODE	E_c VOLTS	ΔE_c VOLTS	I_c $\mu a/cm^2$	CORROSION RATE (MIL/YR)
	Brass	-.10	2024 Al	-.71	.61	5.0	4.49
	410 SS	-.18	2024 Al	-.71	.89	4.0	3.60
	Brass	-.10	4130 Stl	-.61	.51	6.5	3.02
	Brass	-.10	7075 Al	-.74	.64	4.9	2.14
	410 SS	+.18	4130 Stl	-.61	.79	3.8	1.76
	Galvanic Corrosion Rates in Selected Inhibitors						
1% Ammonium Thiocynate in Polyphosphate	Naval Brass	-.29	2024 Al	-.39	.10	.39	.35

Average Corrosion Potentials Over 2 Month Exposure Period for Fire Trol 931

CORROSION POTENTIALS VS Ag/AgCl, VOLTS

Alloy	Naval Brass	304 SS	410 SS	Zinc	4130 Stl	6061 Al	7075 Al	2024 Alc	2024 Al
Potential	-.21	+.04	-.06	-.63	-.17	-.91	-.86	-.86	-.81

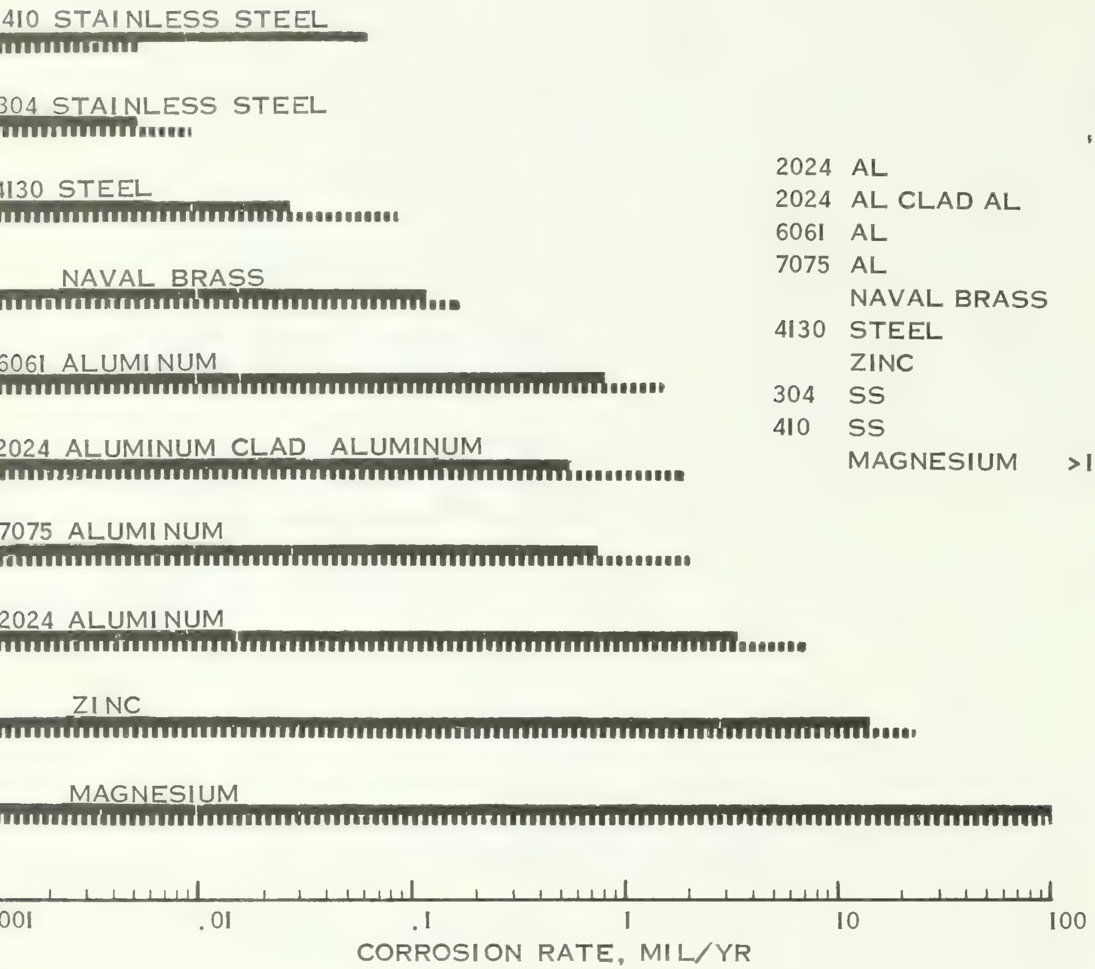
Results of DCB Stress Corrosion Cracking Tests for Inhibitor Screening Phase

RETARDANT	INHIBITOR	ALLOY	CRACK GROWTH OVER 1000 HRS.
Ammonium Polyphosphate	Ammonium Thiocyanate	2024 Aluminum	.15"

Results of DCB Stress Corrosion Cracking Tests

RETARDANT	ALLOY	CRACK GROWTH	K_{IC}	K_{ISCC}	% REDUCTION IN K_{IC}
Fire Trol 931-L	4130 Stl	.976	339.0	162.9	52
Fire Trol 931-L	2024 Al	.079	132.5	121.4	6

GENERAL CORROSION RATES IN FIRE–TROL 931–D



		WEIGHT LOSS	LINEAR POLAR.
2024	AL	7.113	3.376
2024	AL CLAD AL	1.857	.6757
6061	AL	1.530	.6995
7075	AL	2.108	.7578
	NAVAL BRASS	.1743	.1292
4130	STEEL	.0898	.0264
	ZINC	23.29	14.75
304	SS	.0096	.0051
410	SS	.0054	.0605
	MAGNESIUM	>100	>100

APPENDIX C

COMBUSTION RETARDING EFFECTIVENESS TEST DATA AND SUPERIORITY FACTORS

FLAMMABILITY DATA FOR FIRE TROL 931 L

RETARDANT	ACTIVE CHEM. P_2O_5 (G/FT^2)	RATE OF SPREAD (FT/MIN)	REDUCTION IN RATE OF SPREAD (PERCENT)	RATE OF WEIGHT LOSS (G/MIN)	REDUCTION IN RATE OF WT. LOSS (PERCENT)	RESIDUE (GRAMS)	REDUCTION IN FUEL CONSUMED (PERCENT)	AVERAGE SUPERIORITY FACTOR
P. Pine								
1A	3.75	1.08	34	186	43	530	19	.325
1B	4.21	.88	46	177	46	445	10	.370
1C	3.93	.76	54	170	48	510	17	.432
2A	7.49	.50	70	127	61	615	28	.572
2B	7.11	.51	69	129	61	630	29	.571
2C	7.64	.62	62	166	49	620	28	.503
Excelsior								
1A	3.47	.88	71	187	56	245	14	.529
1B	3.47	.95	68	167	61	250	14	.527
1C	3.40	.76	75	167	61	255	14	.565
1D	3.75	.93	69	169	61	270	15	.535
2A	7.22	.54	82	126	71	395	22	.642
2B	7.53	.70	77	166	61	380	21	.596
2C	7.75	.67	78	122	71	420	23	.626
2D	8.74	.37	88	54	87	510	28	.728

FLAMMABILITY DATA FOR FIRE TROL 931 N

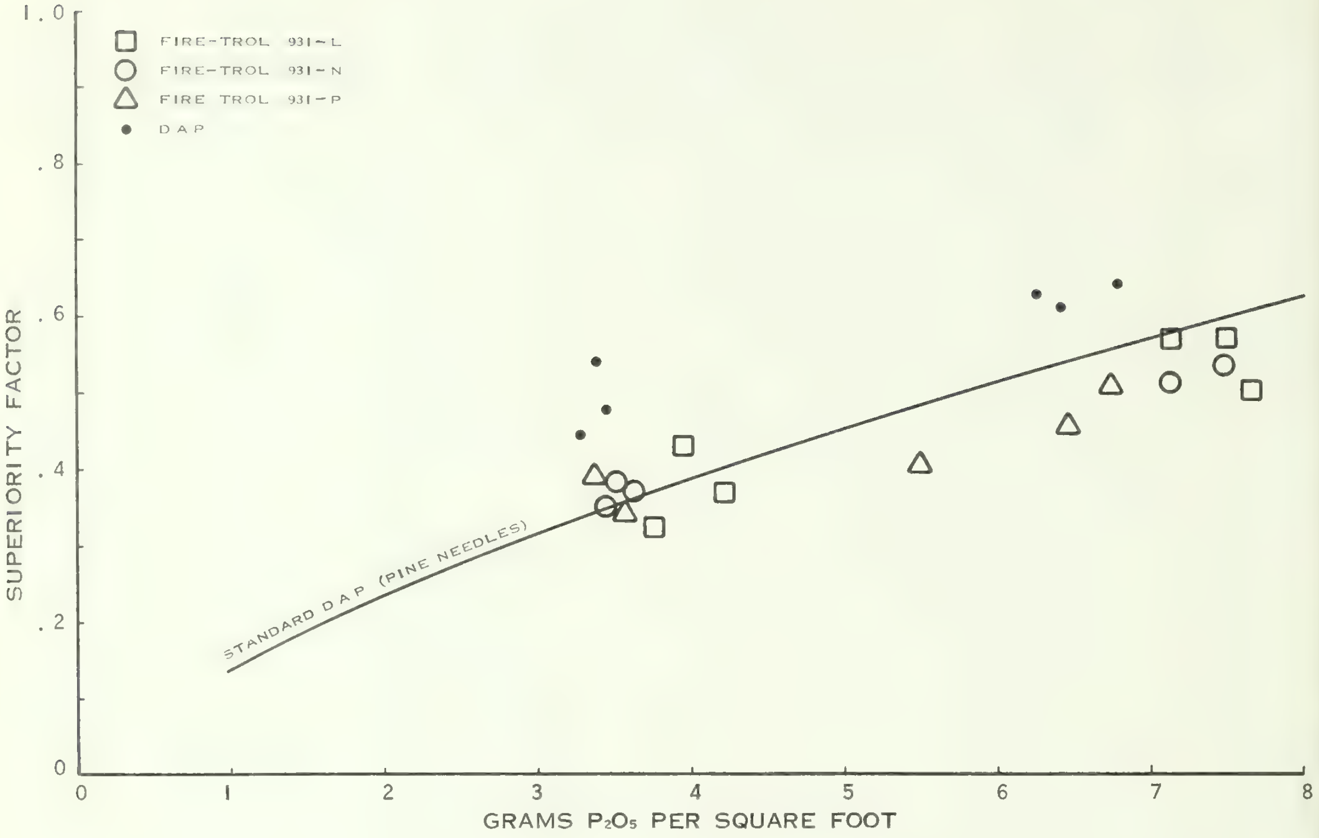
RETARDANT	ACTIVE CHEM. P_2O_5 (G/FT^2)	RATE OF SPREAD (FT/MIN)	REDUCTION IN RATE OF SPREAD (PERCENT)	RATE OF WEIGHT LOSS (G/MIN)	REDUCTION IN RATE OF WT. LOSS (PERCENT)	RESIDUE (GRAMS)	REDUCTION IN FUEL CONSUMED (PERCENT)	AVERAGE SUPERIORITY FACTOR
P. Pine								
1A	3.44	1.06	34	152	54	520	18	.350
1B	3.51	.99	40	227	31	465	12	.371
1C	3.51	.86	48	187	43	490	15	.385
2A	7.69	.60	63			640	30	
2B	7.49	.56	66	152	54	625	29	.537
2C	7.12	.70	57	145	56	690	36	.514
Excelsior								
1A	3.68	.56	84	132	70	305	17	.637
1B	4.45	.80	73	124	71	280	16	.581
1C	4.11	1.07	64	203	53	280	16	.491
2A	7.32	.40	89	102	77	510	28	.708
2B	7.31	.40	89	70	84	435	24	.715
2C	7.56	.48	88			435	24	

FLAMMABILITY DATA FOR FIRE TROL 931 P

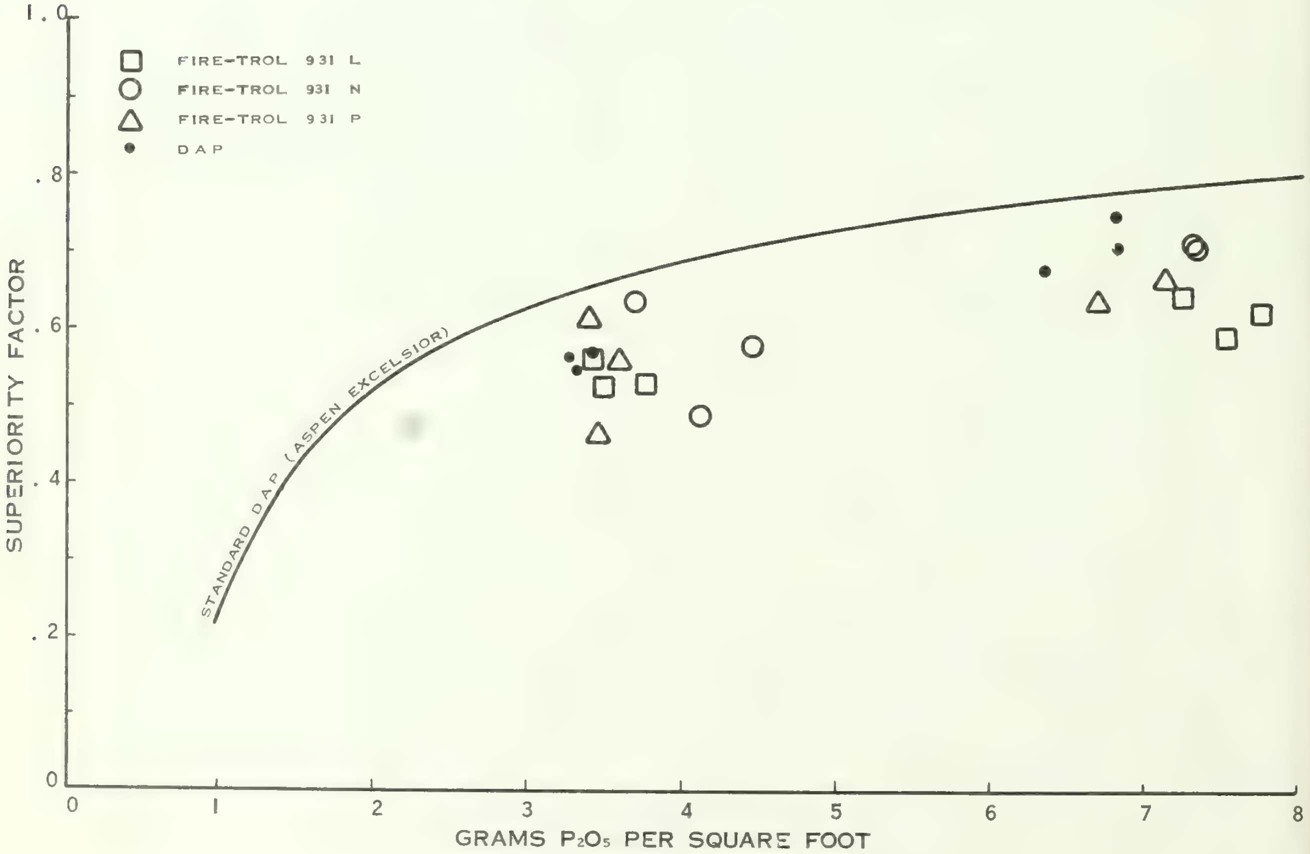
RETARDANT	ACTIVE CHEM. P_2O_5 (G/FT^2)	RATE OF SPREAD (FT/MIN)	REDUCTION IN RATE OF SPREAD (PERCENT)	RATE OF WEIGHT LOSS (G/MIN)	REDUCTION IN RATE OF WT. LOSS (PERCENT)	RESIDUE (GRAMS)	REDUCTION IN FUEL CONSUMED (PERCENT)	AVERAGE SUPERIORITY FACTOR
P. Pine								
1A	3.55	.98	41	197	40	505	16	.346
1B	3.36	.98	41	147	55	530	19	.390
1C	3.52	.99	40	197	40	535	19	.349
2A	5.49	.88	46	168	49	555	22	.406
2B	6.45	.79	52	169	49	640	30	.459
2C	6.74	.63	62	158	52	607	27	.507
Excelsior								
1A	3.58	.94	73	155	65	236	13	.560
1B	3.45	1.39	60	217	51	275	15	.466
1C	3.39	.72	79	129	71	300	17	.614
1D	3.81	.85	72	197	54	197	11	.522
2A	7.10	.70	80	79	82	418	23	.663
2B	6.68	.73	79	125	72	467	26	.640
2C	7.20	.54	82	140	67	430	24	.637

SUPERIORITY FACTOR (Computed)

RETARDANT	Fire Trol 931 L	Fire Trol 931 N	Fire Trol 931 P
Number of Fires	14	10	12
Chemical in Solution			
Percent P_2O_5	8.49	8.28	7.82
Density (G/ML)	1.108	1.106	1.108
Superiority Factor Equations	$Y = .34523 + .03384X$	$Y = .28753 + .0464X$	$Y = .32736 + .03583X$
Treatment Levels			
1 Gal/100 ft^2			
P_2O_5 (G/ft^2)	3.56	3.47	3.28
Retardant S.F.	.47	.45	.45
Std. DAP S.F.	.51	.51	.49
2 Gal/100 ft^2			
P_2O_5 G/ft^2	7.12	6.94	6.56
Retardant S.F.	.59	.61	.56
Std. DAP S.F.	.68	.67	.68
Mean S.F. - All Treatment Levels & All Fuels	.53	.53	.51



□ FIRE-TROL 931-L
○ FIRE-TROL 931-N
△ FIRE TROL 931-P
● DAP
STANDARD DAP (PINE NEEDLES)
SUPERIORITY FACTOR
GRAMS P2O5 PER SQUARE FOOT
1.0
.8
.6
.4
.2
0
0
1
2
3
4
5
6
7
8



□ FIRE-TROL 931 L
○ FIRE-TROL 931 N
△ FIRE-TROL 931 P
● DAP
STANDARD DAP (ASPEN EXCELSIOR)
SUPERIORITY FACTOR
GRAMS P2O5 PER SQUARE FOOT
1.0
.8
.6
.4
.2
0
0
1
2
3
4
5
6
7
8

George, C. W., A. D. Blakely, G. M. Johnson, D. G. Simmerman, and C. W. Johnson
1977. Evaluation of liquid ammonium polyphosphate fire retardants. USDA For. Serv. Gen. Tech. Rep. INT-41, 54 p. Intermountain Forest and Range Experiment Station, Ogden, Utah 84401.

Summarizes the development, history, and operational use of liquid ammonium phosphate and polyphosphate fire retardants since their first use in the early 1960's. Performance of products is discussed and recommendations are made relative to meeting current Forest Service specifications and satisfying current and future operational needs.

KEYWORDS: retardant evaluation, LC, ammonium polyphosphates, liquid fire retardant, liquid fertilizer, USDA specification, LC development, corrosion, pumpability, drop patterns, separation.

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A METHOD FOR DETERMINING FIRE HISTORY IN CONIFEROUS FORESTS OF THE MOUNTAIN WEST

STEPHEN F. ARNO and KATHY M. SNECK

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USDA FOREST SERVICE GENERAL TECHNICAL REPORT INT-42
Intermountain Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture

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General Technical Report INT-42
November 1977

A METHOD FOR DETERMINING FIRE HISTORY IN CONIFEROUS FORESTS OF THE MOUNTAIN WEST

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KATHY M. SNECK earned a B.S. in forestry at the University of Montana and worked 4 years as a forest fire research officer for the Forest Research Institute, CSIRO, Australia. She is now completing a master's degree in forestry at the University of Montana--her thesis presents the fire history of Coram Experimental Forest (east of Kalispell, Montana). She plans to follow a career in fire management and research.

CONTENTS

Page

INTRODUCTION 1

SELECTION OF A STUDY AREA 2

FIELD RECONNAISSANCE 3

  Laying Out Transects 3
  Gathering Data 4

SAMPLING FIRE-SCARRED TREES 11

  Selecting Sample Trees 11
  Collecting Samples 11

LABORATORY ANALYSIS 15

  Preparing Cross Sections 15
  Counting Rings 15
  Correlating Fire Chronologies 17
  Designating Stands 20
  Calculating Fire Frequency 22
  Analyzing Age Classes 23
  Mapping Historic Fires 25

INTERPRETATIONS 27

PUBLICATIONS CITED 27

RESEARCH SUMMARY

This General Technical Report describes a method for investigating the history and ecological influences of wildfire in the inland coniferous forests of western North America.

The method relies on the collection and analysis of cross sections of fire-scarred trees and the identification, from increment cores, of age classes of postfire tree species. In logged areas, fire-scar and age-class data can be gathered from stumps.

The Report covers selection and layout of study areas, and the collection and analysis of samples. The authors tell how to interpret fire frequency, intensity, and size; the influence of fire on stand composition and structure; and the effects of modern fire suppression.

INTRODUCTION

Throughout much of western North America, forest managers are making a transition from a narrow policy of fire control to a broader approach called fire management (Moore 1974). This change reflects their increasing interest in using fire in fuel management, wildlife habitat management, silvicultural improvement, and natural area management. Thus, managers want to evaluate the influence of fire on forest ecosystems. But, to fully understand the role that fire has played, one should learn about the fire history. The following questions should be investigated: what were the (1) average, minimum, and maximum intervals between fires in various forest habitats? (2) sizes and intensities of fires? (3) effects of past fire on forest vegetation, particularly stand composition and age-class structure? (4) effects of modern fire suppression?

This paper outlines a method that a fire management specialist, land use planner, or research forester can use to address these questions. Most of the individual procedures were developed and used in various ways by other fire history investigators. Detailed justification of this method and comparison with various alternatives are not presented here; however, they are discussed by Arno (manuscript in preparation) and can be evaluated by reading some of the most pertinent study reports, such as:

Alberta--MacKenzie 1973, Byrne 1968, Tande 1977
Arizona--Weaver 1951
British Columbia--Howe 1915
California--Wagener 1961, Kilgore 1973, McBride and Laven 1976
Colorado--Clagg 1975
Idaho--Burkhardt and Tisdale 1976, Marshall 1928
Minnesota--Frissell 1973, Heinselman 1973
Montana--Arno 1976, Gabriel 1976, Sneck 1977
New Hampshire--Henry and Swan 1974
New Mexico--Weaver 1951
Oregon--Weaver 1959, McNeil 1975, Soeriaatmadja 1966
Washington--Weaver 1961
Wyoming--Houston 1973, Loope and Gruell 1973, Taylor 1974

The techniques employed are a relatively simple process of aging and correlating dates from fire scars on trees as well as identifying fire-initiated age classes of trees. The procedures were applied on three study areas in the Bitterroot National Forest of western Montana where they provided a detailed analysis of the role of fire since about the year 1600 (Arno 1976). Sneck (1977) recently field-tested the method in an area on the Flathead National Forest that has been more heavily logged and has had less frequent fires than the Bitterroot. As a result, improvements that she suggested have been incorporated here. This method should be applicable to coniferous forests of the western United States and adjacent portions of Canada, inland from the coastal forests.

Manpower and equipment for obtaining fire history information are not extensive. Once the study site has been selected and initial preparation made, estimated manpower allocations are as follows:

Type of Study Area	*Manpower*
1. Small (100 to 300 acres, 40 to 120 hectares), having one or a few closely related habitat types	Principal investigator: 1 to 2 weeks (field investigations and sampling, final analysis and writeup)
	Technician: 2 to 3 weeks (help with fieldwork, preparation and basic analysis of field collections)
2. Large (5,000 to 10,000 acres, 2,000 to 4,000 hectares), having diverse forest habitat types and physiography	Principal investigator: 6 to 8 weeks
	Technician: 10 weeks

About 70 percent of the time is spent in the office (planning, analysis, and writeup) and can be done during any season.

SELECTION OF A STUDY AREA

Topography and forest types should be representative of a larger vicinity to allow for reasonable extrapolation of the study results. If results will be applied to a sizable region--for example, 1,000,000 acres (400,000 ha)--it is advisable to set up three or more large study areas in different parts of the region. A watershed or other logical geographical unit should be selected as a study area and outlined on a large-scale topographic map (7-1/2 minute series or, better, 4 inches per mile). Areas with substantial remnants of unlogged or lightly selection-cut forest are most favorable for study, although it is often helpful, especially in moist forest types, to include some heavily logged areas where stumps can be analyzed for buried (healed over) fire scars. This method can also be used in logged areas where stumps are still relatively sound (stumps 30 or 40 years old are often satisfactory).

Road access should be available at least to the periphery of the study area, and in a large study area a network of trails and roads is helpful.

FIELD RECONNAISSANCE

Laying Out Transects

A network of reconnaissance transects (not statistically based) should be laid out on the topographic map of the study area. As illustrated in figure 1, this network should lead through representative amounts of terrain on all aspects and elevations. Such a network will normally provide a representative sample of the forest types. Transect routes can be established to take maximum benefit of trails and roads for access. Orienting the transects along topographic contours or perpendicularly up one broad slope and down another is quite acceptable. Transects should not follow narrow ridgetops or stream bottoms for miles, because these have vegetative and fire environments that may not be typical of most of the area. Instead, transects should generally traverse broader slopes on all aspects from low to high elevations, and should be well dispersed throughout the study area. Parallel transects can be made along longitudinal or latitudinal lines; however, this approach requires more time for surveying the route and is especially slow in rugged terrain.

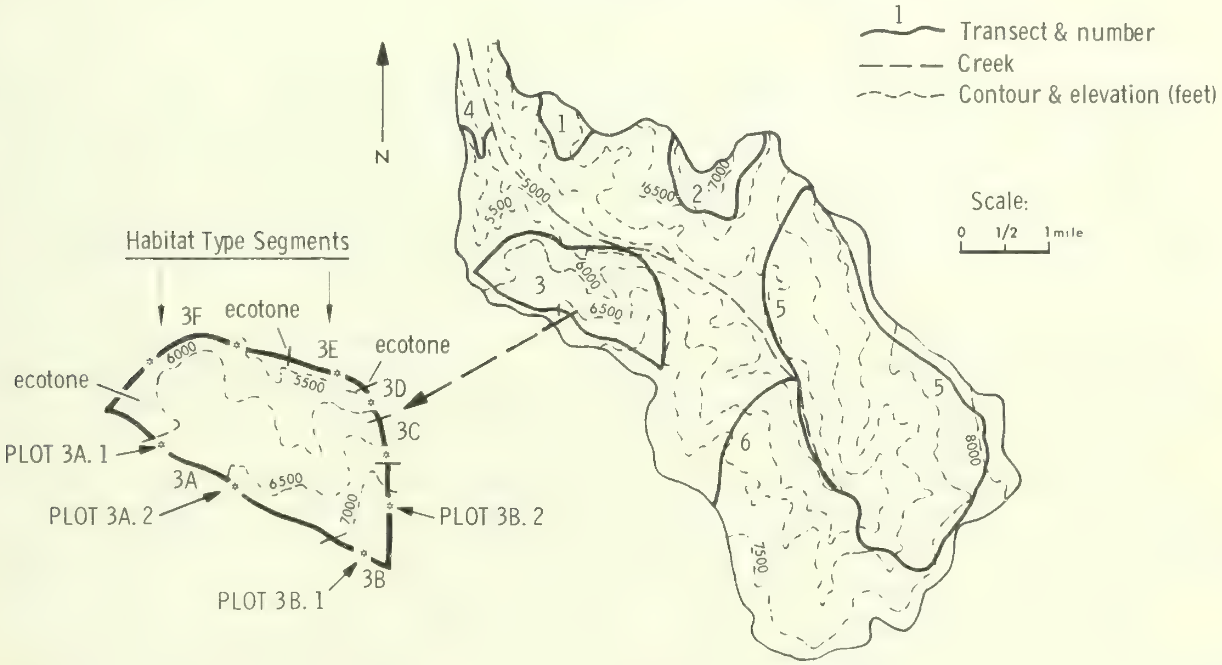


Figure 1.--Topographic map of a study area showing network of transects (which utilized trail and road access) and transect numbering scheme. Enlargement of transect 3 shows habitat type segments (3A, 3B, etc.), ecotones, sample plots (*).

Gathering Data

Recording Habitat Types

A continuous log of the forest habitat types should be kept along the transect route, by means of the most current forest habitat-type classification (or similar, ecologically based stratification of forest environments) applicable to the area. The status of these classifications in the western United States is explained in detail by Pfister (1976). In unclassified areas, it should be possible to adapt a broader system based on potential climax tree species, similar to the series level of a habitat-type classification. Vegetation should be carefully documented on habitat type-stand composition plots (described later using a field-form checklist like figure 2). Logged areas can be habitat typed by extrapolating from similar unlogged sites nearby or by using other techniques described in Pfister and others (1977).

As shown on figure 1, boundaries (ecotones) between each habitat-type segment along the transect should be determined on the ground and drawn across the transect on the topographic map. The location of each habitat-type plot should also be drawn on the map. The completed habitat-type transects can provide a basis for identifying the topographic and elevational characteristics associated with each habitat type (and, optionally, for preparing a habitat-type map of the study area). This will allow for a comparison of the role of fire by habitat type and will aid extrapolation of findings to adjacent areas having similar habitat types.

Obtaining Stand-Composition and Age-Class Data

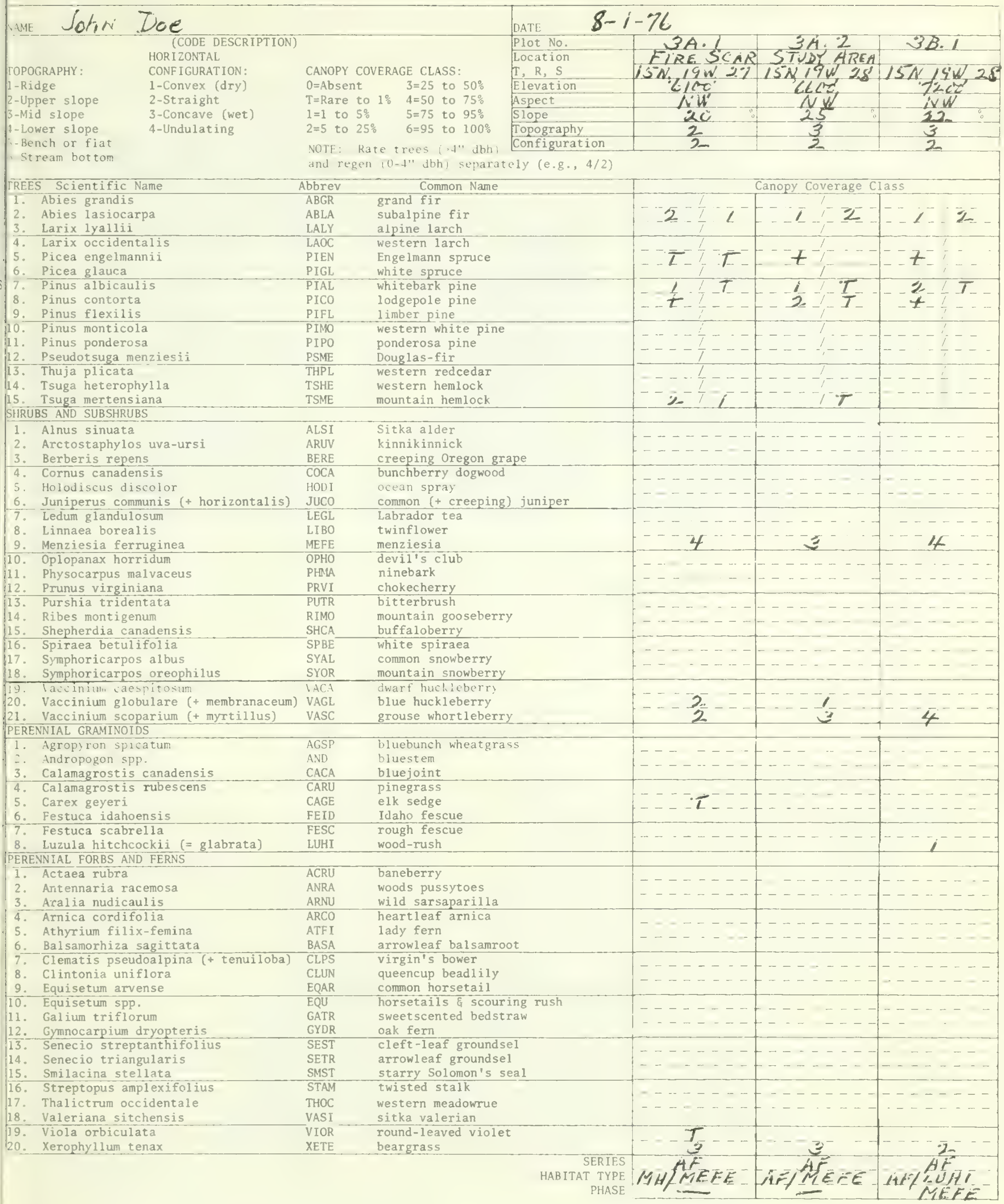
Within each habitat-type segment of the transect, the investigator should subjectively select a site for a 1/10-acre (0.04-ha) plot having representative timber type and stand conditions. He should then record all tree species by 2-inch (5-cm) size classes in the plot. The habitat-type field-form (fig. 2) should be filled out here also.

Next, increment cores should be taken at 1 foot (0.3 m) above ground level to determine the age classes of seral tree species in the stand. Significant quantities of seral species (for example, ponderosa pine in a potential Douglas-fir climax stand or lodgepole pine in a potential subalpine fir climax) commonly regenerate after a fire. Thus age class data will be essential for interpreting the historical effects of fire on stand composition and structure. Where seral trees are unavailable, the climax species can be used with the understanding that they are less likely to have originated after a fire.

A minimum of three trees should be bored for each apparent age-size class. Rings should be carefully counted in the field with a 10-power hand lens. If the three trees representing one size class differ by more than 10 years, additional trees should be bored until each age class is represented by at least three (preferably seral) trees.

Field notes should be taken to describe stand composition (tree species) and apparent age classes along the transects. This will provide valuable information, augmented by the plot and fire-scar data, for interpreting the effects of historical fire.

All cores should be glued into core-mounting boards (fig. 3) for laboratory analysis, and labeled with the location, code number (transect number, habitat-type-segment letter, and plot number), tree species, and diameter at breast height (d.b.h.). A core board is made by cutting grooves in 1- by 8-inch (2.5- by 20-cm) lumber on a table saw. A bead of Elmers or similar "white glue" is spread in the bottom of a groove, the core is then placed in the groove, and a second core board is placed, smooth side



AME John Doe

DATE 8-1-76

(CODE DESCRIPTION)

TOPOGRAPHY:
1-Ridge
2-Upper slope
3-Mid slope
4-Lower slope
-Bench or flat
Stream bottom

HORIZONTAL CONFIGURATION:
1-Convex (dry)
2-Straight
3-Concave (wet)
4-Undulating

CANOPY COVERAGE CLASS:
0=Absent
T=Rare to 1%
1=1 to 5%
2=5 to 25%
3=25 to 50%
4=50 to 75%
5=75 to 95%
6=95 to 100%

NOTE: Rate trees (>4" dbh) and regen (0-4" dbh) separately (e.g., 4/2)

Plot No.	3A.1	3A.2	3B.1
Location	FIRE SCAR	STUDY AREA	
T, R, S	15N, 19W 27	15N 19W 28	15N 19W 28
Elevation	6100	6600	7200
Aspect	NW	NW	NW
Slope	20 %	25 %	22 %
Topography	2	3	3
Configuration	2	2	2

Scientific Name	Abbrev	Common Name	Canopy Coverage Class		
TREES					
1. Abies grandis	ABGR	grand fir	/	/	/
2. Abies lasiocarpa	ABLA	subalpine fir	2 / 1	1 / 2	1 / 2
3. Larix lyallii	LALY	alpine larch	/	/	/
4. Larix occidentalis	LAOC	western larch	/	/	/
5. Picea engelmannii	PIEN	Engelmann spruce	T / T	T /	T /
6. Picea glauca	PIGL	white spruce	/	/	/
7. Pinus albicaulis	PIAL	whitebark pine	1 / T	1 / T	2 / T
8. Pinus contorta	PICO	lodgepole pine	T /	2 / T	T /
9. Pinus flexilis	PIFL	limber pine	/	/	/
10. Pinus monticola	PIMO	western white pine	/	/	/
11. Pinus ponderosa	PIPO	ponderosa pine	/	/	/
12. Pseudotsuga menziesii	PSME	Douglas-fir	/	/	/
13. Thuja plicata	THPL	western redcedar	/	/	/
14. Tsuga heterophylla	TSHE	western hemlock	/	/	/
15. Tsuga mertensiana	TSME	mountain hemlock	2 / 1	/ T	/
SHRUBS AND SUBSHRUBS					
1. Alnus sinuata	ALSI	Sitka alder			
2. Arctostaphylos uva-ursi	ARUV	kinnikinnick			
3. Berberis repens	BERE	creeping Oregon grape			
4. Cornus canadensis	COCA	bunchberry dogwood			
5. Holodiscus discolor	HODI	ocean spray			
6. Juniperus communis (+ horizontalis)	JUCO	common (+ creeping) juniper			
7. Ledum glandulosum	LEGL	Labrador tea			
8. Linnaea borealis	LIBO	twinflower			
9. Menziesia ferruginea	MEFE	menziesia	4	3	4
10. Oplopanax horridum	OPHO	devil's club			
11. Physocarpus malvaceus	PHMA	ninebark			
12. Prunus virginiana	PRVI	chokecherry			
13. Purshia tridentata	PUTR	bitterbrush			
14. Ribes montigenum	RIMO	mountain gooseberry			
15. Shepherdia canadensis	SHCA	buffaloberry			
16. Spiraea betulifolia	SPBE	white spiraea			
17. Symphoricarpos albus	SYAL	common snowberry			
18. Symphoricarpos oreophilus	SYOR	mountain snowberry			
19. Vaccinium caespitosum	VACA	dwarf huckleberry			
20. Vaccinium globulare (+ membranaceum)	VAGL	blue huckleberry	2	1	
21. Vaccinium scoparium (+ myrtillus)	VASC	grouse whortleberry	2	3	4
PERENNIAL GRAMINOIDS					
1. Agropyron spicatum	AGSP	bluebunch wheatgrass			
2. Andropogon spp.	AND	bluestem			
3. Calamagrostis canadensis	CACA	bluejoint			
4. Calamagrostis rubescens	CARU	pinegrass			
5. Carex geyeri	CAGE	elk sedge	T		
6. Festuca idahoensis	FEID	Idaho fescue			
7. Festuca scabrella	FESC	rough fescue			
8. Luzula hitchcockii (= glabrata)	LUHI	wood-rush			1
PERENNIAL FORBS AND FERNS					
1. Actaea rubra	ACRU	baneberry			
2. Antennaria racemosa	ANRA	woods pussytoes			
3. Aralia nudicaulis	ARNU	wild sarsaparilla			
4. Arnica cordifolia	ARCO	heartleaf arnica			
5. Athyrium filix-femina	ATFI	lady fern			
6. Balsamorhiza sagittata	BASA	arrowleaf balsamroot			
7. Clematis pseudoalpina (+ tenuiloba)	CLPS	virgin's bower			
8. Clintonia uniflora	CLUN	queencup beadlily			
9. Equisetum arvense	EQAR	common horsetail			
10. Equisetum spp.	EQU	horsetails & scouring rush			
11. Galium triflorum	GATR	sweetscented bedstraw			
12. Gymnocarpium dryopteris	GYDR	oak fern			
13. Senecio streptanthifolius	SEST	cleft-leaf groundsel			
14. Senecio triangularis	SETR	arrowleaf groundsel			
15. Smilacina stellata	SMST	starry Solomon's seal			
16. Streptopus amplexifolius	STAM	twisted stalk			
17. Thalictrum occidentale	THOC	western meadowrue			
18. Valeriana sitchensis	VASI	sitka valerian			
19. Viola orbiculata	VIOR	round-leaved violet	T		
20. Xerophyllum tenax	XETE	beargrass	3	3	2
		SERIES	AF	AF	AF
		HABITAT TYPE	MH/MEFE	AF/MEFE	AF/LUHI
		PHASE			MEFE

Figure 2.--Sample habitat type-stand composition field form (Pfister and others 1977), with vegetational data from three plots located in figure 1.

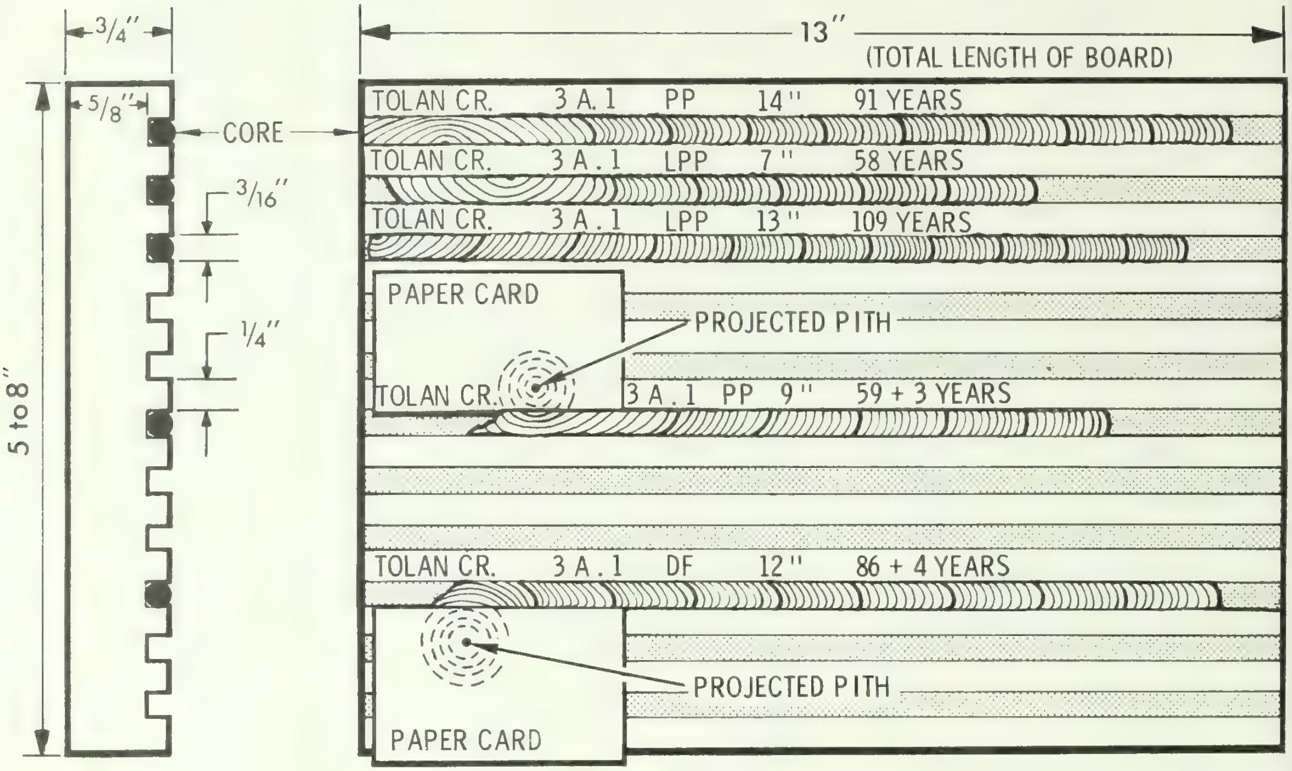

3/4"
5/8"
CORE
3/16"
1/4"
5 to 8"
13"
(TOTAL LENGTH OF BOARD)
TOLAN CR. 3 A.1 PP 14" 91 YEARS
TOLAN CR. 3 A.1 LPP 7" 58 YEARS
TOLAN CR. 3 A.1 LPP 13" 109 YEARS
PAPER CARD
PROJECTED PITH
TOLAN CR. 3 A.1 PP 9" 59 + 3 YEARS
TOLAN CR. 3 A.1 DF 12" 86 + 4 YEARS
PROJECTED PITH
PAPER CARD
END VIEW

Figure 3.--Increment core mounting board, showing increment cores, ring-counting techniques, and labeling system.

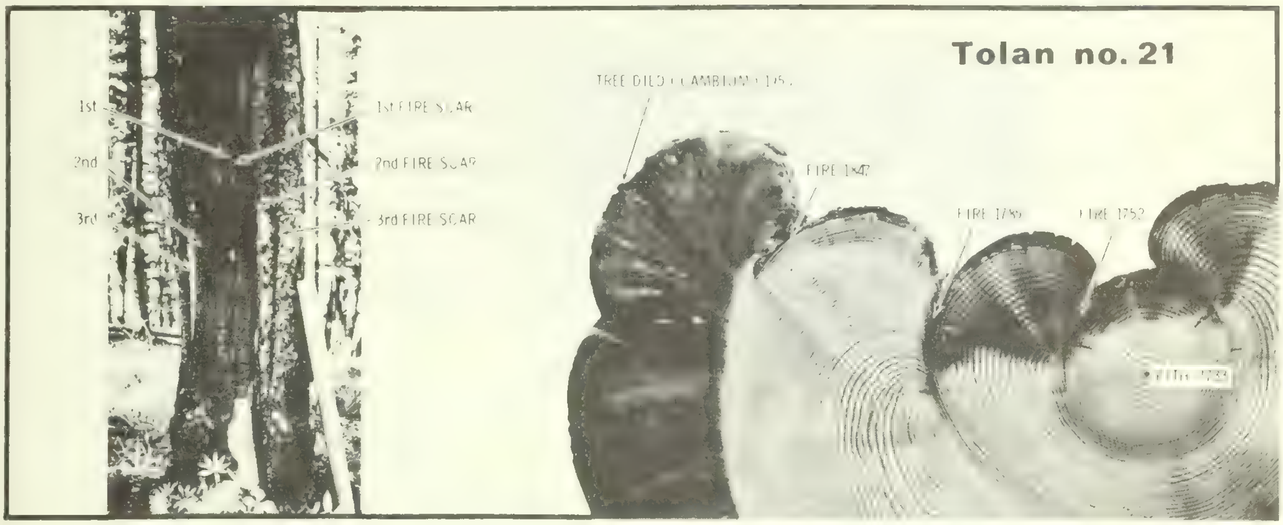
down, atop the first board. The two boards are then held together with a pair of heavy rubber bands. Also, cores can be carried in labeled plastic drinking straws while in the field, then transferred to core boards.

Stand-composition and age-class information can be collected in stands that have been clearcut or heavily logged if stumps are not too rotten or too burnt to age and if the year of logging can be determined. Species can be identified from the bark. Total age can be gathered by cross sectioning sound stumps with a chain saw; ring counts should be confirmed in the lab.

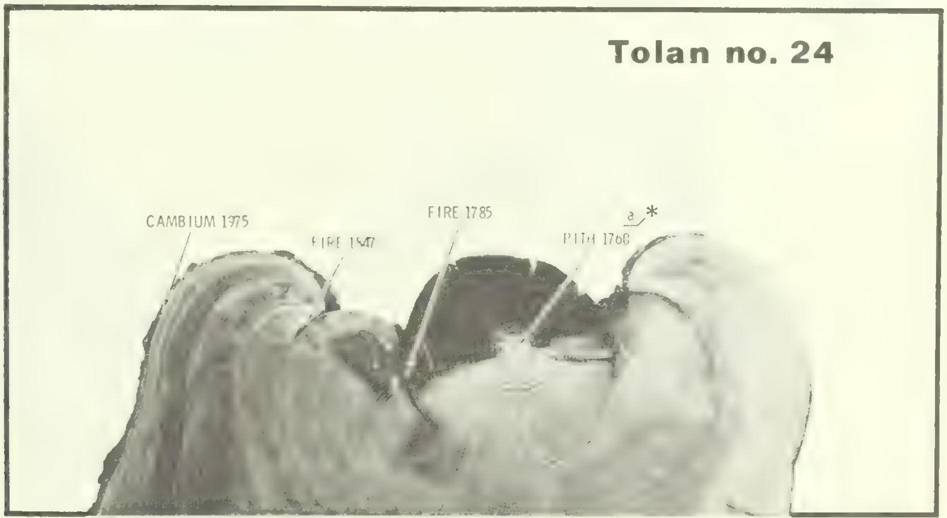
Documenting Fire-Scarred Trees

The investigator and technician should locate and record all fire-scarred trees in a swath of forest along the transect route. By walking parallel about 50 yards (45 m) apart, they can cover a swath about 100 yards (91 m) wide in relatively open forests. They should keep constant watch for the oldest "catfaced" trees available. (Catface is a term for an open scar resulting from one or more fires.) On each catface, the number of external fire scars should be counted. Each individual fire scar has a separate fold or band of healing tissue, often appearing on both sides of the catface. Sometimes these folds are partially or wholly burned off by subsequent fires, but usually a portion of each fold remains at least on one side of the catface a foot (0.3 m) or more above the ground. Figure 4 shows some examples of catfaces and corresponding cross sections of the fire scars. Catfaces are most prevalent on the upslope side, especially on old-growth trees that lean upslope.

Figure 4.--Examples of multiple fire scars on trees and scar patterns in cross sections.

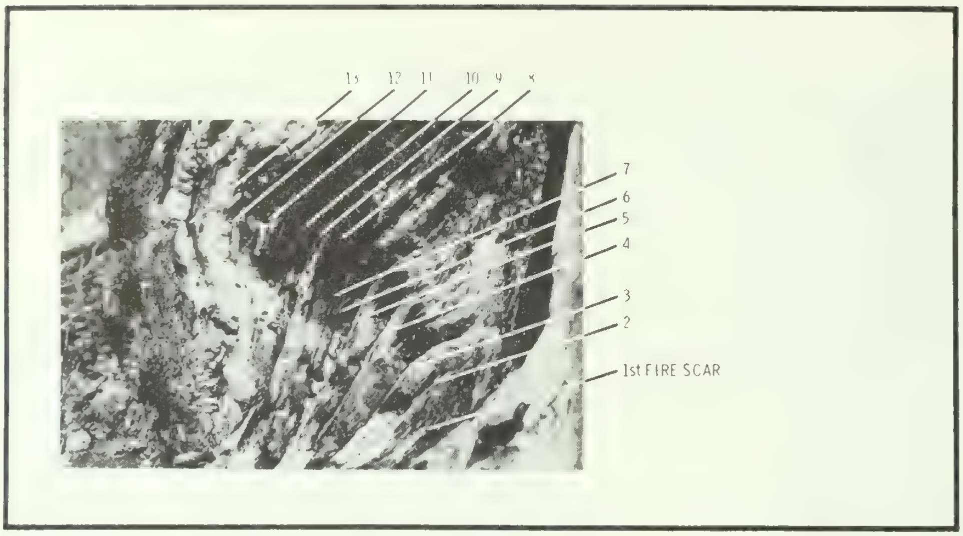


4-A. Lodgepole pine with three fire scars

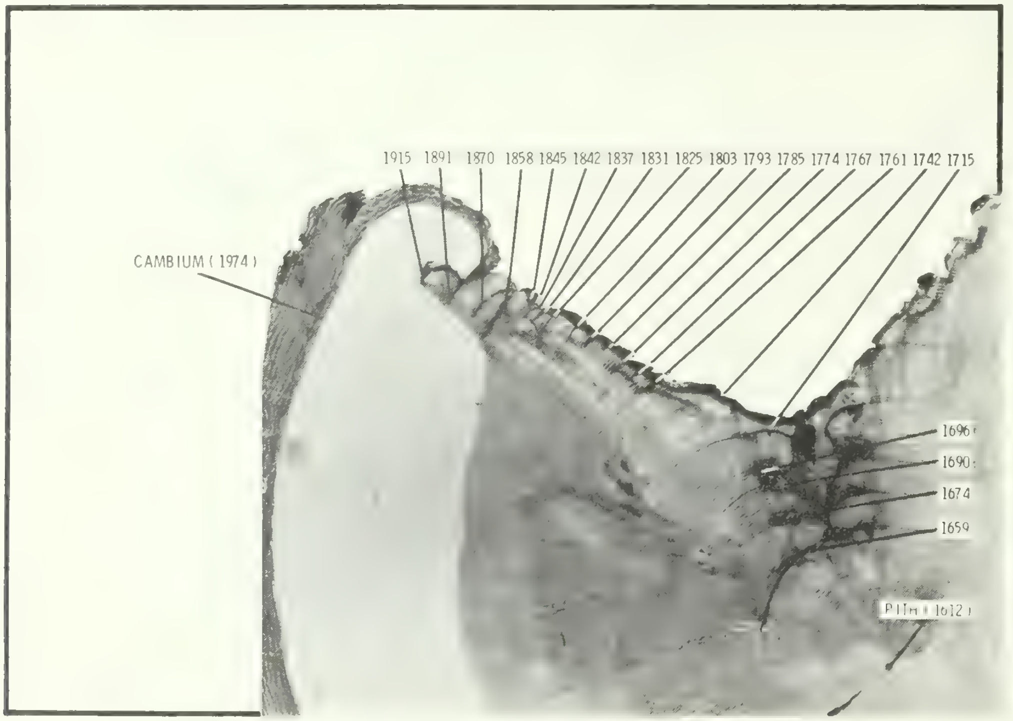


a/* This tree probably germinated about 1755 and apparently represents regeneration from the 1752 Fire shown in part A.

4-B. Nearby lodgepole pine with two fire scars



4-C. Old ponderosa pine stump with 13 externally visible scars



4-D. Ponderosa pine cross section with 21 fire scars

Investigators must learn to differentiate fire scars from scars caused by fallen trees, frost cracks, root rot, and bear, rodent, or beetle damage. (These are described more fully later.) Also, they must recognize those healed-over fire scars which are indicated only by a bark seam, generally on the upslope side. Field experience will clarify the scarring characteristics of each tree species. Char on the outer bark confirms at least one fire, probably within the last 70 years. Char on the surface of any scar in a catface is evidence that a fire occurred *after* the year of that scar.

A few trees having the largest number of relatively sound fire scars in each stand should be recorded and marked for revisiting. In stands having many old-growth trees with multiple scars, it is not necessary to also tally all the younger trees with only one or two scars. The following data should be recorded for each tree in a "Log of Fire-Scarred Trees":

(1) transect number, habitat-type-segment letter, and scarred-tree Roman numeral
(2) species
(3) d.b.h.
(4) maximum height of catface
(5) number of externally visible scars
(6) elevation
(7) aspect
(8) remarks such as descriptive location and recommendation for sampling

This information (table 1, part A) will provide the basis for selecting sample trees. Each of the trees in the log should be plotted by numeral on the transect topographic map.

Fire-scarred trees can also be identified in stands that have been clearcut or heavily logged during the past few decades by systematically examining stumps. Because fire scars on low stumps are not readily apparent at a distance, careful inspection is necessary. Fire scars may have healed over and thus not be visible on the outer edge of stump, but they can be seen in the rings (on top). Fire-scarred stumps are recorded similarly to fire-scarred trees.

Table 1.--A "Log of Fire scarred Trees' examined in the field reconnaissance (part A), and the log of trees actually sampled (part B), in study area

PART A. LOG OF FIRE-SCARRED TREES

Transect number, h.t. segment letter, and scarred-tree numeral	Species	d.b.h.	Maximum height of cat-face	(Apparent) number of external scars	Elevation	Aspect	Remarks
		Inches	Feet		Feet	Degree	
1A-I	PP	24	6	7	4,650	110	Across bridge, 200 ft below rock outcrops, good cross section
1A-II	PP	29	7	13	5,050	90	Below large Douglas-fir snag, good c.s.
1A-III	PP	32	7	11	4,750	100	100 yds below ridgetop, good c.s.
1A-IV	LPP	20	6	4	4,800	120	Flagged close to 1A-III, slightly rotten
1B-I	PP	49	20	4	5,800	190	Possibly lightning struck, good c.s.
1B-II	PP	31	16	2	5,500	170	In dense stand of young PP, good c.s.
1B-III	PP	22	10	4	5,600	200	Double trunk, 50 yds east of trail
1B-IV	PP	20	8	1	5,500	180	In dense stand of young PP, not a good sample
1C-I	DF	24	10	2	5,400	80	Below ridge, flagged
1C-II	DF	16	3	4	5,400	65	Below ridge
1C-III	PP	23	15	6	5,650	70	On ridge spur, good c.s.

PART B. LOG OF SAMPLED TREES

Sample tree number	Reconnaissance code	Species	d.b.h.	Maximum height of cat-face	(Apparent) number of external scars	(Actual) number of internal scars	Elevation	Aspect	Habitat type and phase	Photo number	Remarks
			Inches	Feet			Feet	Degree			
1	1A-I	PP	24	6	7	9	4,650	110	DF/AGSP	1	335° from bridge, 200 ft below rock outcrops
2	1A-II	PP	29	7	13	14	5,050	90	DF/CARU PIPO	2	315° from bridge, below large DF snag
3	None[1]	PP	23	5	12	13	5,050	80	DF/AGSP	3	120 yd S of tree no. 2
4	1A-III	PP	32	7	11	13	4,750	100	DF/AGSP	4,5	100 yd below ridgetop
5	1B-I	PP	49	20	4	4	5,800	190	PP/FEID	13,14	Lightning struck
6	None[1]	PP	19	3	4	4-5	5,200	200	PP/FEID	15	100 yd N of road above pullout
7	None[1]	PP	24	3	6	7	5,650	200	PP/FEID FESC	16	Dead snag (died ca. 50± yr ago)
8	1B-III	PP	22	10	4	5	5,600	200	PP/FEID FESC	17	Double trunk, 50 yd E of trail
9	1C-II	DF	16	3	4	5	5,400	65	DF/PHMA PHMA	18	Below ridge 150 feet
10	1C-III	PP	23	15	6	6	5,650	70	DF/PHMA	19	On ridge spur

[1] Not previously discovered.

SAMPLING FIRE-SCARRED TREES

Selecting Sample Trees

After completing the field transects, one can examine the Log of Fire-scarred Trees and make preliminary selections for sampling. Generally, two or three sample trees should be selected for each half mile (0.8 km) of a given habitat-type segment on each transect. Some transect segments may not have fire-scarred trees because few trees survived the most recent fire. In this case, increment cores (age-class data) and transect field notes will provide fire history information within that segment.

On larger study areas having many miles of transects, distances between sample groups can be increased. (Nevertheless, the investigator should sample groups of two or three trees in close proximity in order to correlate fire-scar chronologies.) If this intensity of sampling is not feasible, establish a few small study areas with representative terrain and vegetation, correlate the findings, then extrapolate results to the larger area. An example of this approach is provided by Arno (1976).

Trees with the greatest number of externally visible, individual fire scars have the highest priority for sampling. Avoid sampling trees whose ring-count sequence may be obscured by rot.

Where candidate sample trees have similar numbers of scars and soundness, other factors can be considered. For instance, the investigator may choose to sample a ponderosa pine in preference to a Douglas-fir or western larch because the former usually has clearer scar rings. A small, old-growth tree can be chosen in preference to a larger dominant tree having a similar scar sequence.

Final selections of sample trees and stumps should be recorded on a field sheet and on a map that will be used to relocate them for taking cross sections.

Collecting Samples

Return to the chosen sample trees, watching for better scar trees that may have been overlooked. Inspect each chosen tree to verify that the data supporting its selection were accurate. Check especially the maximum number of fire scars and determine the best place to cross section the trunk to obtain the full sequence of scars as well as the pith and cambium. Photograph the catface. Assign the tree a permanent number and record it in the "Log of Sampled Trees" (part B of table 1), which includes information listed in the Log of Fire-scarred Trees, plus the number of cross-sectional scars, habitat type, and photograph number. Also, plot and label the sample tree's location on the topographic map.

Sectioning techniques suggested here provide *primarily* for study needs while *secondarily* minimizing visual impact and structural damage to trees. In some areas (National Parks, wildernesses, private lands) it may be necessary to reverse the above priorities. In that case, thin wedge-shaped sections, not necessarily penetrating to the pith, can be taken (McBride and Laven 1976), with a handsaw if necessary.

Small sample trees--those less than a foot (0.3 m) thick at stump height--should generally be felled, cutting them off either well below or well above the point on the trunk where the clearest scars are apparent. After felling, cut the stump or downed tree to obtain the clearest cross section with the maximum number of fire scars.

Large, relatively sound trees are usually best sampled by taking a partial cross section from one side of the catface. As illustrated in figure 5, the pith, fire scars, and cambium can usually be obtained by severing only about 10 to 15 percent of the stem. A roller or sprocket-tipped chain saw (20- or 24-inch bar) is used to make parallel, horizontal cuts 1-1/2 to 2 inches (4 to 5 cm) apart. These extend from the pith to the cambium across the clearest portion of the scar sequence, on only one side of the catface. The cut is made just deep enough to insure that it goes behind the deepest penetration of each scar so the count can be made in unscarred tissue. (Normally this will be 3 to 4 inches deep.) Then the tip of the saw is pushed in vertically along the back of the parallel cuts, from cambium to pith. The saw wound can be painted with an asphalt-base tree paint to prevent entrance of insects or disease (McBride and Laven 1976).

Inspect the partial cross section to insure that it does extend behind each scar. Draw arrows perpendicularly across any broken parts to aid reassembly. (Glue the parts back together in the lab.) Write the sample tree number (table 1, part B) in ballpoint ink on all pieces in two places on the back of the cross section, where it will not be sanded off. Also, write the sample number conspicuously on the tree or stump or use a small metal tag for this purpose.

Compare the number of fire scars on the cross section with scars on the catface. Small scars that may represent scrapes or rodent damage when the tree was a sapling should be denoted. Scrape scars resulting from falling trees and scars from mountain pine beetle attacks should be analyzed and discounted in the field also. Scrape scars are generally longer than fire scars, and the remains of the fallen tree causing the scrape can usually be found. Scars from beetle attacks often result from dieback of the cambium at more than one place along a given annual ring; these scars have an irregular shape and may be correlated to a known epidemic year.

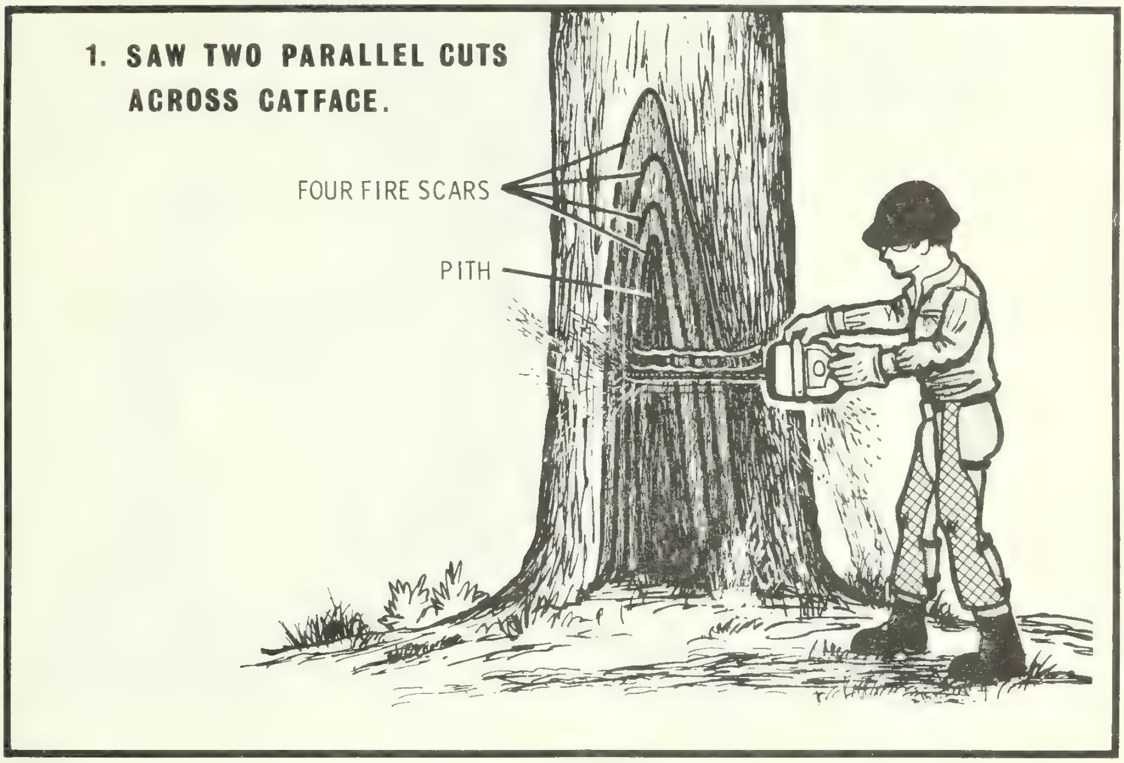
Basal scars may be caused by root rot (*Armillaria mellea*), but these usually extend up basal root buttresses rather than forming in the hollows between buttresses like fire scars. Also unlike fire scars, rot scars are not correlated with the upslope side of trees. Various cankers or animals also cause scars; these are not usually basal, bear little resemblance to fire scars, and do not char wood.

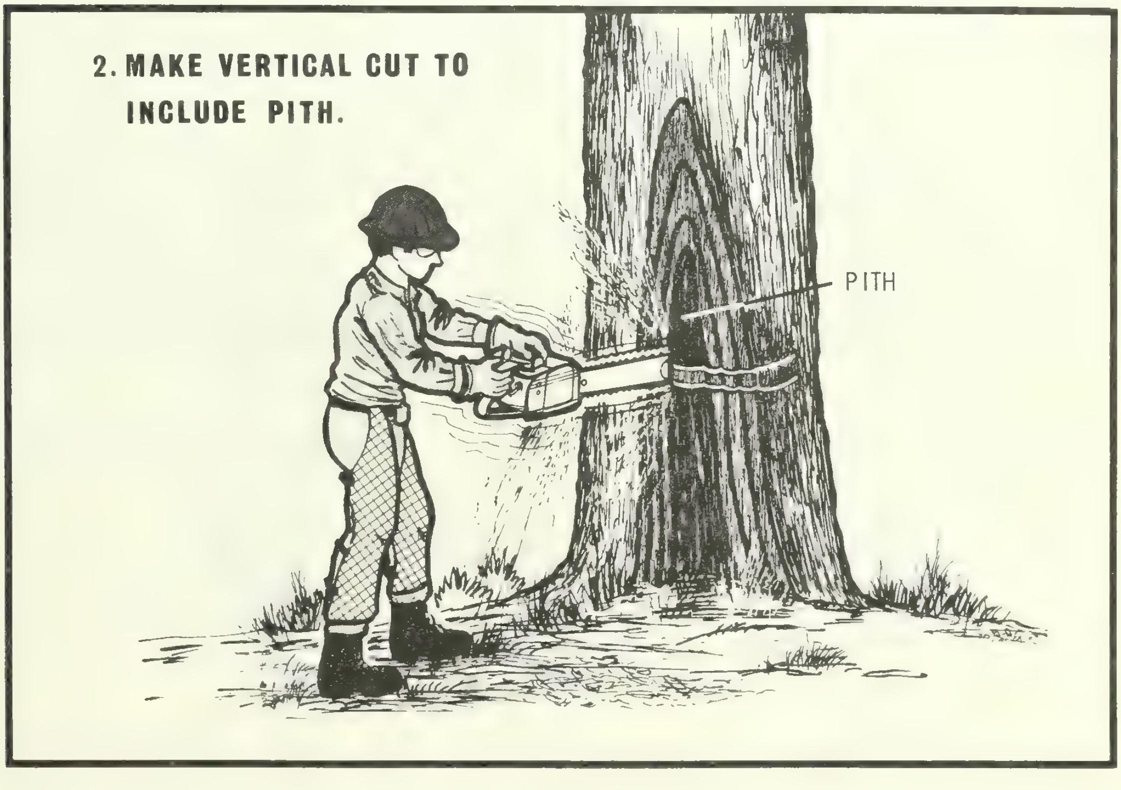
After counting the fire scars on the sample tree's cross section, enter the total in the Log of Sampled Trees (part B of table 1). Examine each tree and cross section carefully in the field because the catface and additional cross sections will not be available for checking in the laboratory.

When sampling logged areas, photograph the top of each stump (vertically), using markers to pinpoint each fire scar and the pith. Preliminary ring counts can be made in the field, using a 10X hand lens if necessary. Cross sections of sound stumps can be cut and taken to the lab for documentation and for ring counting with a microscope. If the stump is not sound enough to section, obtain the best estimate of fire scar and pith dates, counting the rings several times if necessary.

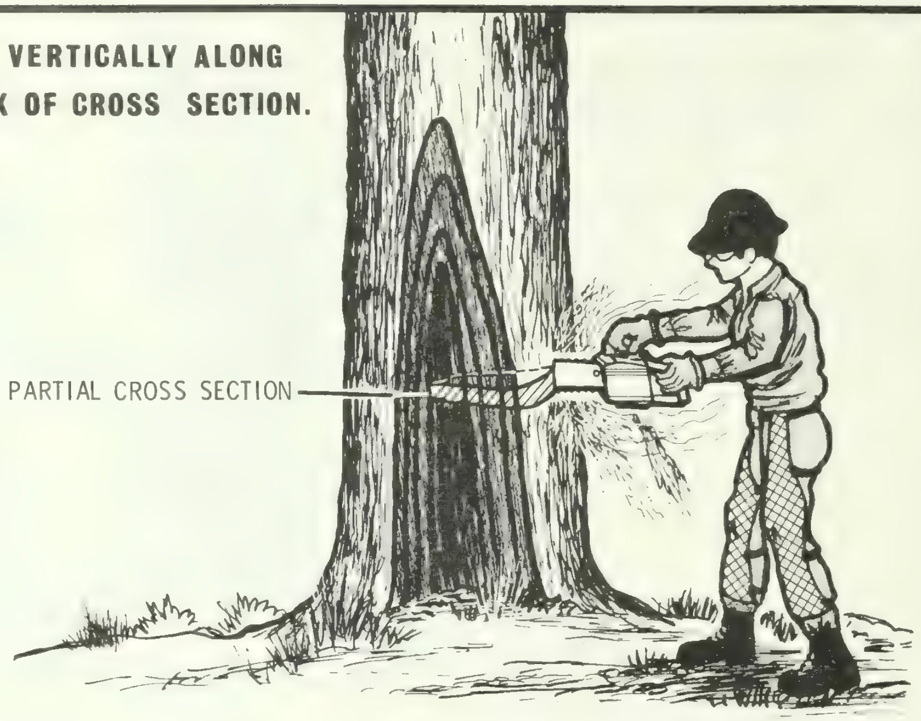
To facilitate transporting and handling, it is desirable to minimize both weight and size of the cross sections. Full cross sections often need only be about an inch thick, and if decay is not extensive, the back 40 percent of the circle, not including pith or scars, can be sawed off and left in the field. Partial cross sections should not be made thicker or deeper than necessary. The chain saw and a few cross sections, along with an extra quart of fuel, can be carried in an extra-large, aluminum-frame backpack.

Figure 5.--Collecting a partial cross section from a large tree.

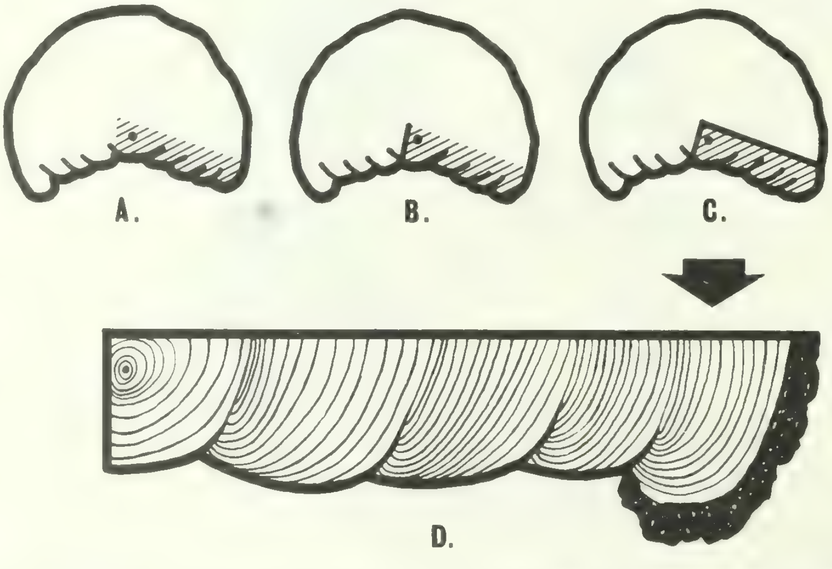

1. SAW TWO PARALLEL CUTS ACROSS CATFACE.
FOUR FIRE SCARS
PITH


2. MAKE VERTICAL CUT TO INCLUDE PITH.
PITH

3. CUT VERTICALLY ALONG BACK OF CROSS SECTION.



4. CUTS MADE IN CROSS SECTION OF TREE.



These sampling procedures may require some adjustment where fires have destroyed extensive stands. In such regions, study areas should be made large enough to include some of the boundaries of the big burns. The extent of such burns is often detectable in patterns of forest development seen on aerial photographs. Fire scar *and* total age information can be obtained from (1) scattered surviving trees within the burn, (2) both young and old trees (age classes) killed by the fire, (3) pockets of surviving forest, and (4) trees at the perimeter of the burn. Regeneration can be aged to help date the large burn itself. Historical accounts are often available for dating large and destructive fires that have occurred within the last 100 years or more.

LABORATORY ANALYSIS

Preparing Cross Sections

After each day of sampling, cross sections should be laid out for drying in a heated building. Within a week or two, surfaces should be dry enough to sand, so that rings can be more accurately counted and examined. A disk sander attached to a lightweight electric drill, will suffice.

Begin sanding with coarse disks (40 to 50 grit) having the heaviest paper backing available. Then use fine and very fine (125 grit) sandpaper as necessary to bring out the rings. It is not necessary to sand the entire surface, but only a moderately wide band along and immediately behind the scars to allow for a complete ring count. Other sanding techniques, including hand sanding, are preferred by some investigators.

Counting Rings

A variable-power binocular microscope (7X to 25X) is usually essential for accurate counting. (Sometimes this can be borrowed or rented.) Select the clearest side of the cross section and count inward from the cambium. Count 1 year to the outer edge of the outermost band of (darker) summerwood, and continue to count from one band of summerwood to the next. Wetting the counting area with water and occasionally slicing obscure rings with a razor blade facilitates counting. With a very sharp red pencil, mark a dash (-) along every 10th ring and a plus (+) on each fire-scar ring as illustrated in figure 6. An alternative for wood with extremely fine rings is to puncture the ring with a fine dissecting needle. A fine red dot should also be placed near such punctures because they may disappear if the wood is wetted.

If the junction of the scar ring and undamaged tissue is obscured by pitch or rot, count past the scar ring to a clear ring beyond the scar. Then follow the clear ring around past the obstruction and count back up to the scar surface.

Record the number of years back to the most recent fire and between each previous fire as shown in table 2. Rings should be counted carefully by one person and then verified by another. On samples where some of the ring sequence is unclear, the opposite side of the cross section (or the opposite facet of the catface, in the case of a full cross section) should also be counted.

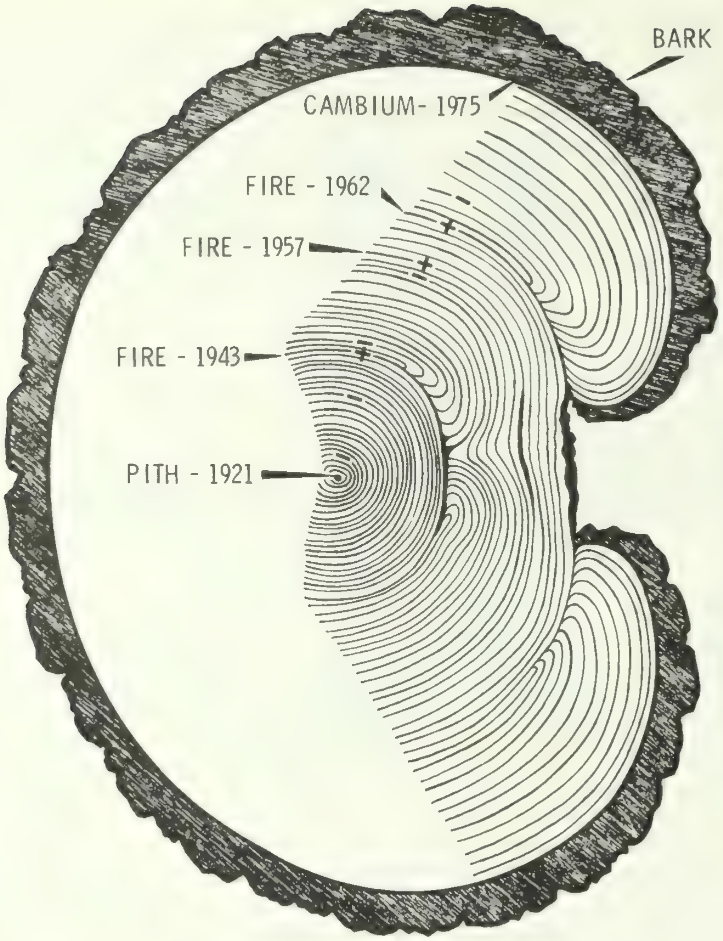


Figure 6.--How rings are counted on a fire-scar cross section. (Every 10th year in from the cambium is marked "-"; scar rings are marked "+".)

Table 2.--An example of ring-count tabulations from seven trees sampled in one stand. F = fire; P = pith

Tree Number													
1		2		3		4		5		6		7	
Cambium	1975	Cambium	1975	Cambium	1975	Cambium	1975	Cambium	1975	Cambium	1975	Cambium	1975
-84 rings	1891F	-86 rings	1889F	-86 rings	1889F	-86 rings	1889F	-86 rings	1889F	-99 rings	1876F	-108 rings	1867F
-30 rings	1861F	-20 rings	1869F	-38 rings	1851F	-30 rings	1859F	-87 rings	1802F	-29 rings	1847F	- 23 rings	1844F
-15 rings	1846F	-16 rings	1853F	-49 rings	1802F	-40 rings	1819F	-38 rings	1764P	-44 rings	1803F	-103 rings	1741P
-25 rings	1821F	-24 rings	1829F	-35 rings	1767F	-17 rings	1802F			-55 rings	1748F		
-34 rings	1787F	-18 rings	1811F	-11 rings	1756F	-17 rings	1785F						
-46 rings	1741F	- 9 rings	1802F			-29 rings	1756F						
		-36 rings	1766F			-17 rings	1739F						
		-16 rings	1750F										
		-14 rings	1736P										

Correlating Fire Chronologies

Ring counts from each individual tree may not be entirely accurate or coincide because of pockets of obscured rings or rot, or due to occasional missing rings or false rings. More accurate estimations of the actual fire years can be developed by combining records from several trees into a "master fire chronology."

To correlate records from individual trees, arrange them on a large sheet of paper (such as 10 line/inch graph paper). The chronology from each tree is shown in a vertical column, and the trees should be arranged in a logical geographic ordering so that neighboring trees appear in adjacent columns (fig. 7). The top line of each column represents the date of the cambial ring, usually the year the samples were cut. Each inch (10 squares) downward represents 10 years.

After the 10-year intervals are labeled on the edge of the graph and adjacent trees are ordered, each individual tree chronology is plotted. The cambial-ring year is shown as a dash and the pith year as "P." If the pith was not obtained, the earliest ring on record is shown as an "E." Cross sections that were exceptionally clear (without periods of very narrow rings or partially obscured growth) are given added weight: their scar years are marked with an "X." On cross sections where some rings are slightly obscured and dates are approximate, scar years are marked with a solid dot. On cross sections especially difficult to interpret, scar years are marked with an open dot.

Next, total the number of trees scarred each year on the right, as shown in figure 7. (Totaling is done for the entire study area if it is small, or for each geographic subdivision of a larger study area.) The probable fire years can now be determined by inspecting the plotted chronologies, giving more weight to tree records shown with an "X," and using the largest totals of individual scars as an indication of the probable fire year. Fire records (including maps of burned areas) and historical accounts should be examined; often these can be used to verify the year of fires occurring within the past century.

Inspection of this chart (exemplified by fig. 7) may reveal that part of the record for a certain tree is consistently a few years out of sequence with the established probable years (for example, tree number 1 in fig. 7). Often such an individual chronology can be brought into sequence by adding a few years at one point in time, thus moving its scar dates back. This phenomenon evidently results from missing rings and usually occurs during a period when the tree grew at an exceptionally slow rate. It probably represents a temporary cessation of growth caused by defoliation or severe fire injury. Craighead (1927) found that some ponderosa pines stopped forming annual rings for as many as 5 years after defoliation and extreme fire injury, although they remained alive and ultimately resumed growth.

In other cases, it may be possible to synchronize an individual tree's fire chronology with those of its neighbors by moving its scar dates forward slightly (subtracting a few years). This may be an indication of false rings. These are rather faint and often discontinuous. In the case of cross sections that cannot easily be correlated with the emerging master fire chronology, it is important to reexamine the ring counts and the probable origin of any questionable scars.

Unless a tree has definite scars from two fires within 3 years of each other, it is best not to hypothesize separate fires occurring on the same area at such short intervals. This suggestion is made because minor ring errors present in most samples do not allow for precise detection of such close-together fire years without the conclusive evidence of a dual scar. Fires occurring 4 or more years apart will be distinguishable on the chronology graph. Ring errors and diminishing sample size decrease the accuracy of fire-scar records more than 250 years old; nevertheless, fire frequency trends and

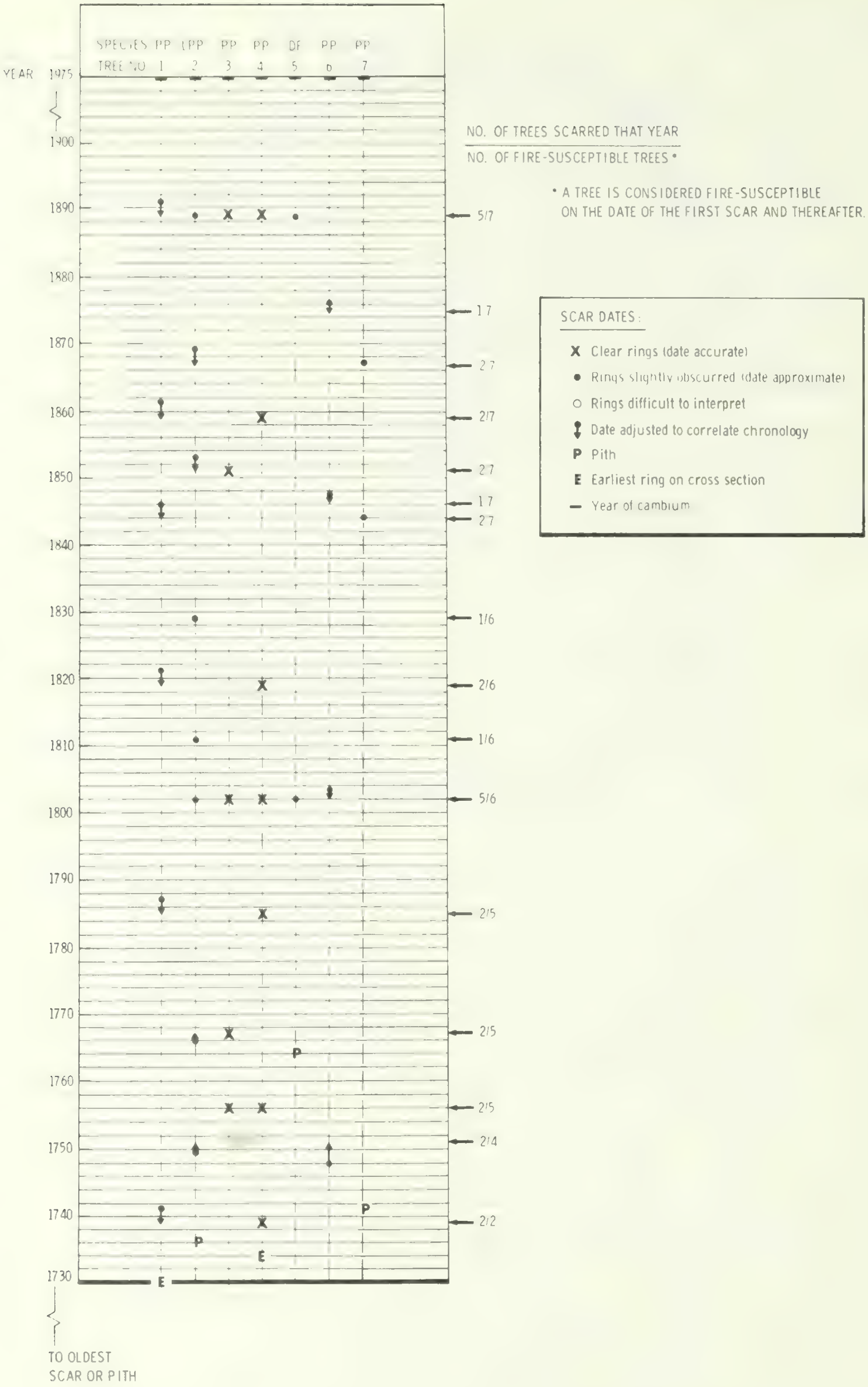


Figure 7.--Graph of the fire-scar chronologies from the seven trees in table 2, showing adjustments to obtain a master fire chronology for the stand.

approximate fire years can be determined by correlating fire records extending back 300 years or more on a few trees.

When the preliminary master chronology is completed, individual tree chronologies should be adjusted to definite fire years and recorded in a revised master fire chronology for use in further analysis. The revised chronology (table 3) lists fire years by stand; it is explained more fully in the next section. At this point it may be possible to integrate fire-scar sequences obtained from stumps and dead snags whose cambial-ring year is unknown. The intervals between fire scars on the dead samples can be compared with the intervals found on nearby living trees. (The year of historic logging operations or settlement can be determined by correlating fire scars found on remaining stumps, or at the butt of logs in cabins, with the fire chronology.)

Table 3.--The master fire chronology for a large study area, showing the number of sample trees scarred during each fire year in each stand and indicating fires that caused conifer regeneration (modified as an example from Arno 1976)

Fire year	STAND									Total number of scars (45)
	A.1 (4)*	B.1 (5)	B.2 (4)	B.3 (2)	D.1 (6)	D.2 (6)	D.3 (4)	E.1 (3)	E.2 (6)	
1935	--	--	--	--	1	--	--	--	--	1
1908	3	--	--	--	1	--	--	--	--	4
1898	1	--	--	--	--	--	--	--	--	1
1892	4	3^{r}	--^{r}	1	2^{r}	--	--^{r}	--	--	10
1889	--	--	--	--	2	--	--	--	$2^{r?}$	4
1886	2	--	--	--	--	--	--	--	--	2
1881	4	2	--	--	--	--	--	--	--	6
1871	3	$1^{r?}$	2	2	1	3^{r}	--^{r}	1^{r}	--	13
1863	3	3	1^{r}	--	2^{r}	--	--	--	--	9
1855	--	--	1	--	--	--	--	--	--	1
1847	3	3	2	2	5^{r}	5^{r}	3^{r}	--$^{r?}$	--	23
1842	4	--	--	--	--	--	--	1	--	5
1838	--	--	--	1	--	--	--	--	--	1
1828	3	--	2	--	--	--	--$^{r?}$	--	--	5
1821	--	2^{r}	--^{r}	1	3	--	--^{r}	1^{r}	--	7
1817	3	1	--	--	--	--	--	--	--	4
1811	--	--	--	1	--	1	--	1^{r}	2^{r}	5
1803	4	$1^{r?}$	1	--	--	--	--	--	--	6
1794	--	1	1^{r}	--	--	--	--	--	--	2
1785	3	4	--	1	3^{r}	5^{r}	4^{r}	7^{r}	4^{r}	31
1779	1	--	--	1	--	--	--	--	--	2
1769	--	--	1	--	--	--	--	--	--	1
1766	2	--	--	--	--	--	--	--	--	2
1757	--	1	--	1	2^{r}	1	1	5	--$^{r?}$	11
1752	--	3	--	1	1	1^{r}	3	2	--$^{r?}$	11
1750	4	--	--	--	--	--	--	--	--	4
1747	--	1	1^{r}	--	--	1	--	1	--	4
1743	--	--	--	--	--	--	--	1	--$^{r?}$	1
1734	--	--	1	--	--	1	--	--	--	2
1730	--	--	--	$1^{?}$	--	--	--	--	--	$1^{?}$
1720	1	2	--	--	--	--	2	--	--	5
1710	1	--	1	1	--	--	--	--	--	3
1698	--	--	--	--	1	--	--	--	--	1
1686	1	1^{r}	--	--	--	--	--	--	--	2
1677	--	--	--	--	1	--	--	--$^{r?}$	--	1
1670	--	--	--	--	--	1	--	--	--	1
1664	--	--	1	--	--	--	--	--	--	1
1658	--	--	--	1	2	--	--	--	--	3
1636	--	--	--	--	1	--	--	--	--	1
1632	--	--	--	--	--	--	--	$1^{r?}$	--	1
1611	--	--	1	--	--	--	--	--	--	1
1595	--	--	--	--	--	--	--	$1^{r?}$	--	1
1587	--	--	1	--	--	--	--	--	--	1
1574	--	--	1	--	--	--	--	--	--	1
Total scars	50	29	18	15	28	19	13	22	8	202

* Number of sample trees.

^{r} Fires causing conifer regeneration based on stand age-class samples.

? Data weak.

Table 4.--Fire frequencies between 1735 and 1900 in three study areas stratified by habitat-type groups on the Bitterroot National Forest (modified as an example from Arno 1976)

					Onehorse		Tolan		West Fork	
Habitat-type groups (potential climax) (Pfister and others 1977) (1)	Descriptive location (2)	General elevations (3)	Dominant trees with continued fire exclusion (most abundant tree first) (4)	Dominant overstory before 1900 (most abundant tree first) (5)	No. of stands (No. of trees) (6)	Mean fire-free interval (min-max interval) (7)	No. of stands (No. of trees) (8)	Mean fire-free interval (min-max interval) (9)	No. of stands (No. of trees) (10)	Mean fire-fre interval (min-max interval (11)
		Feet								
A. Pinus ponderosa/Festuca idahoensis Pseudotsuga menziesii/Agropyron spicatum Pseudotsuga/Calamagrostis, P. ponderosa phase	Valley edge	3800-5000	Douglas-fir ponderosa pine	ponderosa pine	1 (11)	6 years (2-20)	1 (4)	11 years (2-18)	1 (4)	10 years (2-18)
B. Pseudotsuga/Physocarpus malvaceus Pseudotsuga/Calamagrostis (except Cal. phase) Pseudotsuga/Symphoricarpos albus Pseudotsuga/Vac. globulare (except Xerophyllum phase)	Montane slopes	4200-6200	Douglas-fir	ponderosa pine Douglas-fir lodgepole pine western larch	5 (46)	10 years (3-31)	3 (11)	16 years (4-29)	4 (19)	19 years (2-48)
C. Abies grandis habitat types	Moist canyon	4300-4700	grand fir	western larch lodgepole pine Douglas-fir	1 (7)	17 years (3-32)	--	--	--	--
D. Pseudotsuga/Calamagrostis, Calamagrostis phase Pseudotsuga/Vac. globulare, Xerophyllum phase Abies lasiocarpa/Xerophyllum tenax Abies lasiocarpa/Menziesia ferruginea Abies lasiocarpa/Linnaea borealis	Lower subalpine slopes	6000-7500	subalpine fir Douglas-fir	lodgepole pine Douglas-fir	1 (9)	17 years (3-33)	3 (16)	27 years (5-62)	3 (13)	28 years (5-67)
E. Abies lasiocarpa/Luzula hitchcockii Abies lasiocarpa-Pinus albicaulis/Vac. scoparium Pinus albicaulis-Abies lasiocarpa	Upper subalpine slopes	7500-8600	subalpine fir whitebark pine	whitebark pine lodgepole pine	1 (3)	41 years (8-50)	2 (14)	30 years (4-78)	2 (14)	33 years (2-68)

Designating Stands

On large study areas, stands should be delineated to aid analysis of fire frequencies, as follows: List all the habitat types encountered at sample-tree sites and arrange them in an ecological order (for instance, by climax series and from dry-to-moist or warm-to-cold within each series). Record the numbers of the trees sampled in each habitat type. Group minor habitat types on the study area with more prevalent ones that are closely related. List the elevation, aspect, and percent slope at each sample tree and summarize these for each major habitat type. Wherever site parameters overlap substantially, major habitat types can be combined. The goal is to establish habitat-type groups that can be extrapolated to adjacent areas. Table 4 shows an example of such groups used on a fire history study in the Bitterroot National Forest.

After some of these habitat-type groups have been tentatively established, plot all sample trees on a topographic map of the study area and write in the habitat-type group found at each of these points. Inspect the map to see if it shows several (4 to 10) sample trees on the same habitat-type group within areas of a few hundred acres. If sample trees in a given habitat-type group are more dispersed than this, enlarge or redefine the habitat-type groups so that several sample trees from each habitat-type group occur within areas of a few hundred acres.

These assemblages of sample trees (on similar habitat types) should be outlined on the map, and will now be referred to as "stands." Figure 8 shows an example of such stands outlined on a topographic map. The final habitat-type groups should be assigned a letter code (A, B, etc.), and each stand a number; thus "B.3" is the code designating the third stand in habitat-type group B. Stands should be shown by their letter-number code on the map.

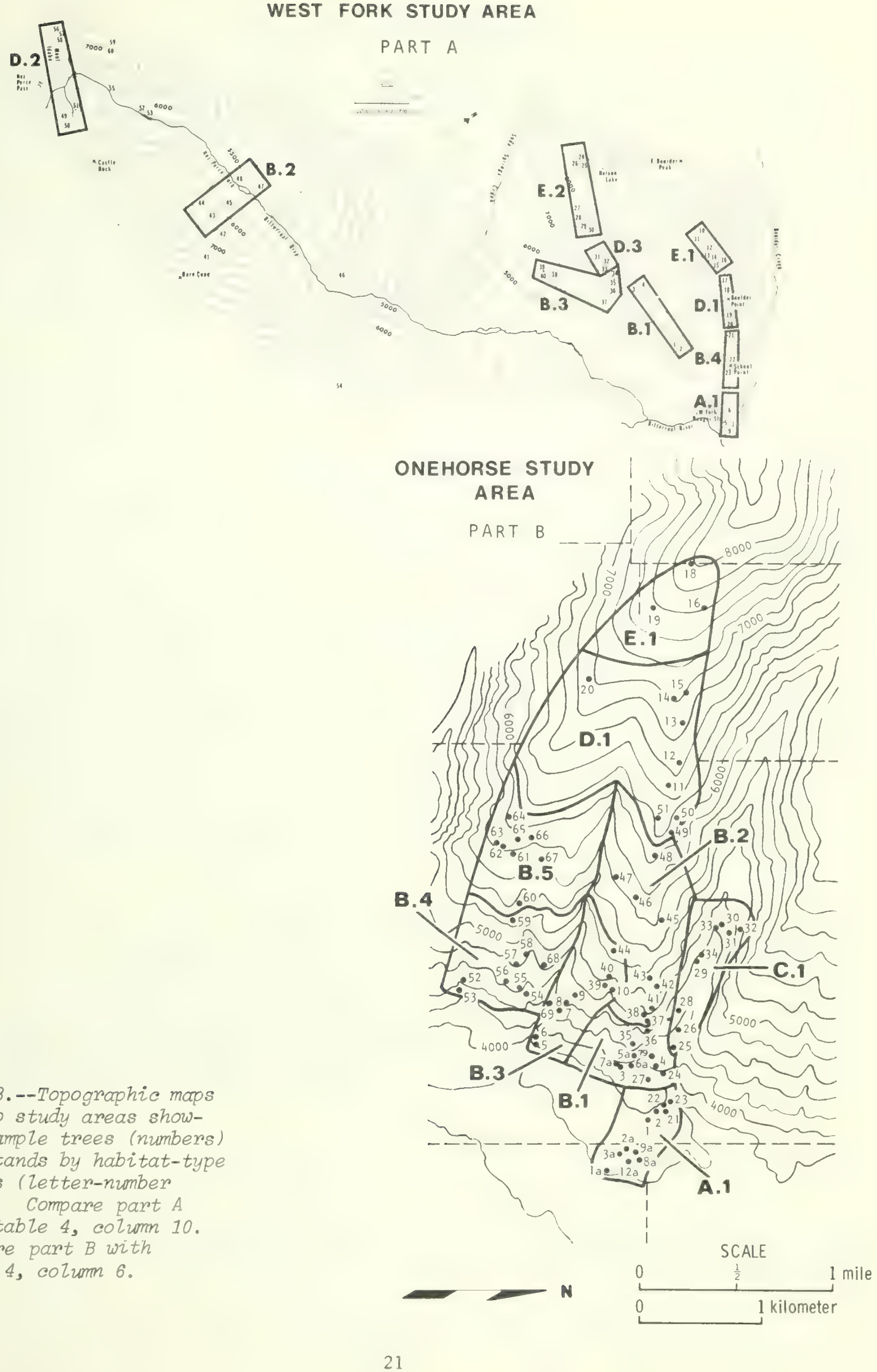


Figure 8.--Topographic maps of two study areas showing sample trees (numbers) and stands by habitat-type groups (letter-number code). Compare part A with table 4, column 10. Compare part B with table 4, column 6.

Calculating Fire Frequency

The stands and habitat-type groups can now be used for calculating fire **frequencie** (fire-free intervals) on an area basis. First, however, logical time periods must also be established for calculating fire frequencies. For instance, the most recent period (of perhaps 40 to 60 years, depending upon the area) can be assigned as the "fire suppression" period, reflecting the time period when organized suppression was well established and effective.

By contrast, suppression activities were generally minimal in forested areas of th Mountain West prior to 1900; thus that year might be chosen as the end of the "historic fire" period, reflecting the time when forest fires were caused primarily by lightning and native Indians. In some areas miners or settlers may have set many forest fires in the late 1800's, necessitating the delineation of still another fire period (for example, "settlement-era fire period" 1860-1910).

The beginning date chosen for analysis of the "historic fire" period will depend upon how far back the fire-scar records extend. It can be chosen arbitrarily but independently of actual fire-scar years. For instance, in one study (Arno 1976) the year 1735 was selected because it was the earliest date when at least five sample trees were alive in each stand, and thus could have recorded a fire. Later, two additional areas were studied in the same National Forest, and it was determined that each had adequate fire-scar records extending back at least to 1735. Consequently, 1735 to 1900 was then used as a standardized period enabling direct comparison of relative frequencies among all the study areas.

Before deciding upon fire frequency periods, graph the number of sample trees scarred during each fire year and the total number of "fire-susceptible trees" (trees already having been scarred at least once) in the sample, as illustrated in figure 9. Note that sample size diminishes markedly toward early years of the record, and take this into account when evaluating fire frequencies throught the record. Identify and consider any obvious changes in historic fire frequencies during the period of record when establishing frequency periods.

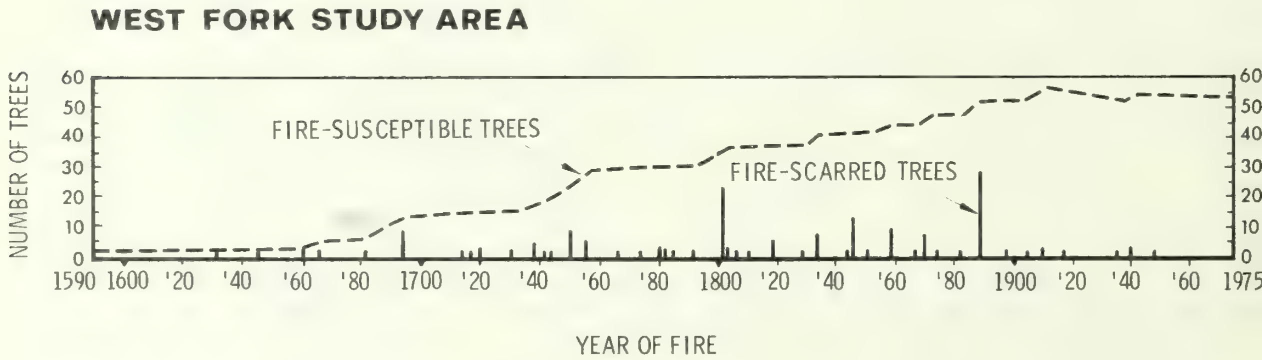


Figure 9.--Number of sample trees scarred each fire year and the total number of fire-susceptible trees in the sample (data from Arno 1976). A tree is considered fire susceptible on the date of the first scar and thereafter.

Table 5.--An example of fire frequency calculations for different stands within a single study area (Arno 1976). Stand locations are shown in figure 8B, Onehorse Study Area

Stand	No. of sample trees	Time period 1735 to 1900					
		No. years in period	÷	Total no. fires	=	Fire frequency	Minimum and maximum fire-free interval
						Years	Years
A.1	11	165	÷	29	=	5.7	2 & 20
B.1	10	165	÷	24	=	6.9	3 & 21
B.2	9	165	÷	18	=	9.2	3 & 28
B.3	10	165	÷	15	=	11.0	3 & 31
B.4	9	165	÷	24	=	6.9	3 & 15
B.5	8	165	÷	12	=	13.8	3 & 31
C.1	9	165	÷	10	=	16.5	3 & 32
D.1	9	165	÷	10	=	16.5	3 & 33

After the "historic fire frequency" period has been established, see how far back in time comparable frequencies were recorded. For example, in figure 9 the analysis period was 1735 to 1900, but it was reasoned that comparable frequencies extended back to about 1630 (see also table 3). Thus, rates established on the basis of a 165-year interval were apparently representative for a period of about 270 years (1630 to 1900).

It may be desirable also to calculate fire frequencies for the transition period (for example, 1900 to 1925) between the "historic" and "suppression" periods.

An example of fire frequency calculations for such periods is shown in table 5. The mean, minimum, and maximum fire-free intervals are shown for each stand. Mean intervals can be averaged for all stands in a habitat-type group. For example, the five stands in habitat type group B, table 5, have a mean fire-free interval of 10 years--this mean is shown in column 7 of table 4. This facilitates comparison of fire frequencies from one study area to another in similar habitat types, as shown in table 4. Also, comparing values from the "historic" and "suppression" periods will indicate the effect of suppression on fire frequency.

Analyzing Age Classes

The first major step in age-class analysis is to count annual rings on the increment cores gathered in field transects. Counts should be made using a variable-power binocular microscope, with the cores wetted, shaved, and sanded as necessary. Counts begin at the cambium and progress to the pith as was done in cross-section analysis. Every 10th ring (outer edge of summerwood band) should be marked with a fine red line (or a dissecting-needle puncture) and every fifth ring with a dot. Counts are made to the innermost ring or the pith and written on the core board next to the field data for that tree, as shown in figure 3.

Where an increment core missed the pith, the number of additional rings to the pith is estimated by considering the curvature and thickness of the innermost rings. As illustrated in figure 3, it is helpful to draw the circles represented by the arc of the inner rings, using a compass, and then extrapolate a similar ring width to the pith. The estimated number of additional years to the pith is then written next to the ring count with a plus sign (for example, "86 + 4").

After the counts are completed and verified, they should be tabulated by plot. Total ages of trees from each plot are listed in chronological order as shown in figure 10. To obtain the total age, add an estimate of the number of years for establishment

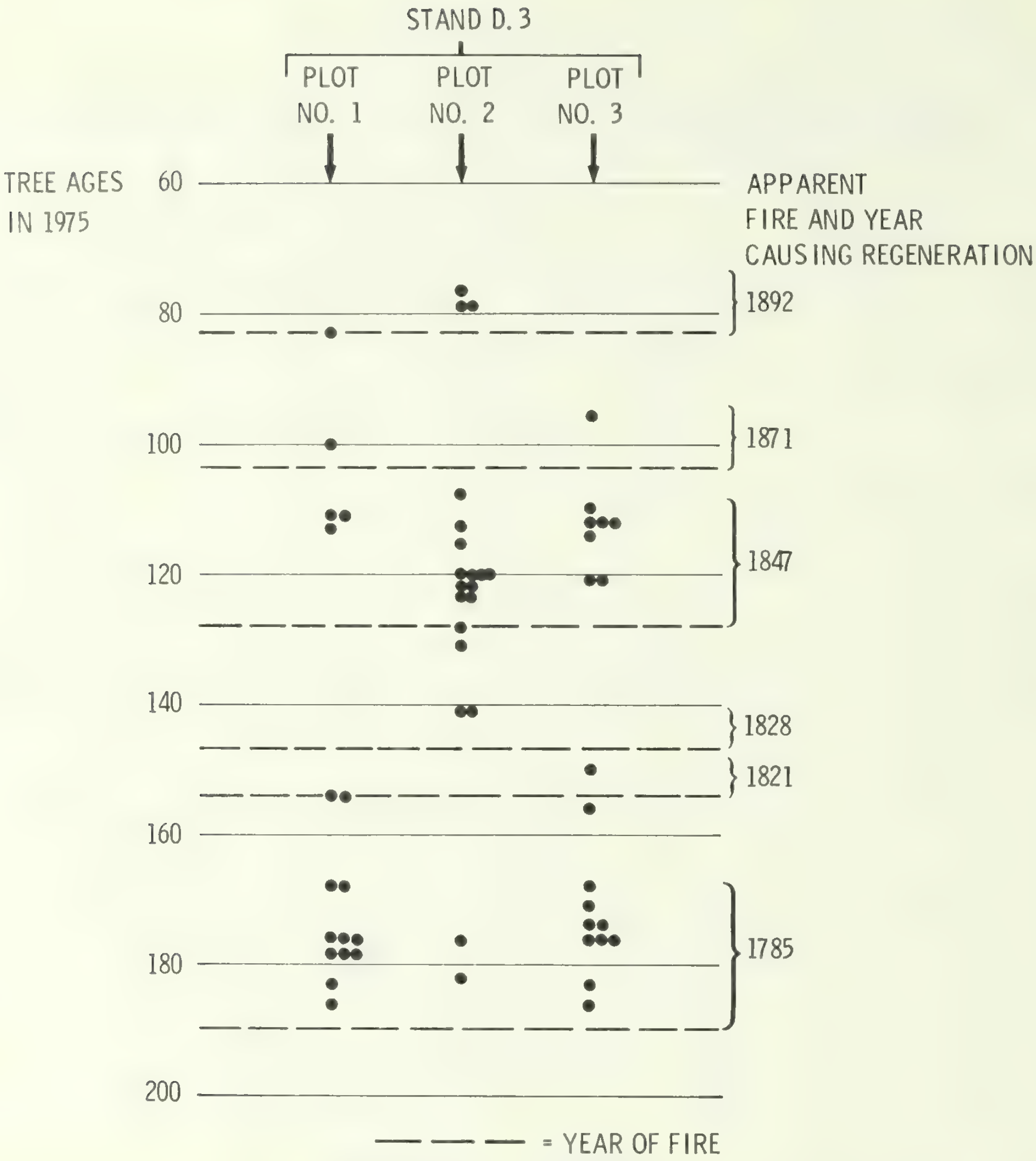


Figure 10.--Age-class designations based upon increment borings of seral trees taken in stand D.3 shown in table 3. Each dot represents total tree age, based on an increment core plus 5 years to reach boring height (1 foot).

and growth to boring height (1 foot, 30 cm). Such factors can be worked out by cutting and aging large numbers of seedlings of various species on various sites. However, considering all the variables, it may be necessary to use a general factor--for example, 5 years for trees bored at 1 foot on the Bitterroot National Forest (Arno 1976). The increment-boring data can be augmented by including the total age of cross-sectioned, fire-scarred trees with the sample from the nearest appropriate plot; only seral species should be used, however.

List the total ages of individual trees by plot, inspect them, and designate possible age classes as in figure 10. At least two similar ages are necessary for designating an age class. Because of field sampling procedures, most age classes will be identified by three or more trees.

Once the tentative age classes have been assigned, based on the oldest tree in each class, the next step is to test for correlations between age classes and the fire-scar chronology. Consult the study area map and find the stand number (fig. 8) that applies to each age-class plot. Plots isolated from designated stands should be analyzed separately, afterwards.

The next step is to examine apparent correlations between each tentative age class and the fire years identified on that stand. For example, if an age class is 115 years (total age of the oldest trees in the class) in 1975, one would expect it to have resulted from a fire occurring only one or a few years before 1860. We can check the master fire chronology (table 3) to see if a fire was detected (via scars) in that stand a few years prior to 1860. Ten or twelve years might be considered to be a reasonable maximum interval for initial establishment after fire on most sites. Longer intervals are reasonable after very large stand-destroying fires.

If there is no fire-scar evidence during the preceding years and the age class seems rather definite, inspect fire-scar records from neighboring stands. If they show a definite fire, one can assume that it actually spread into this stand although it did not scar the sample trees. Another possibility is that very few trees in the entire area survived that fire. If this is the case, age-class data from other plots and transect notes will confirm it. Age classes not ascribable to any of the above situations apparently are not related to fire.

Considerable insight regarding the historic role of fire in age-class structure of forests can be obtained by incorporating the age-class data into the fire chronologies for each stand as shown in table 3. If these data show that age classes of seral species were apparently established without fire, this suggests that other agents such as epidemics of native insects or diseases or massive blowdowns were responsible. If these data (table 3) show that certain fires were not followed by pronounced regeneration, regeneration may have been destroyed by subsequent fire before the trees had grown large enough to withstand fire. (The fire records should be checked for this possibility.) Another possibility is that creeping ground fires did not kill enough of the stand to allow for a new age class.

Mapping Historic Fires

The size and perhaps the configuration of historic fires can be found by plotting fire evidence on a small map of the study area (fig. 11). Map each fire year (from the master chronology) separately. Indicate locations of trees scarred that year by placing an "s" next to the dot representing that tree. Indicate regeneration attributed to that fire year by drawing an "r" in the correct plot location. Using this evidence of the fire, one can now roughly outline the area covered. Aerial photos and fire suppression records may also be useful. Heinselman (1973) and Tande (1977) have made detailed maps showing areas covered by many individual fires during the course of two centuries.

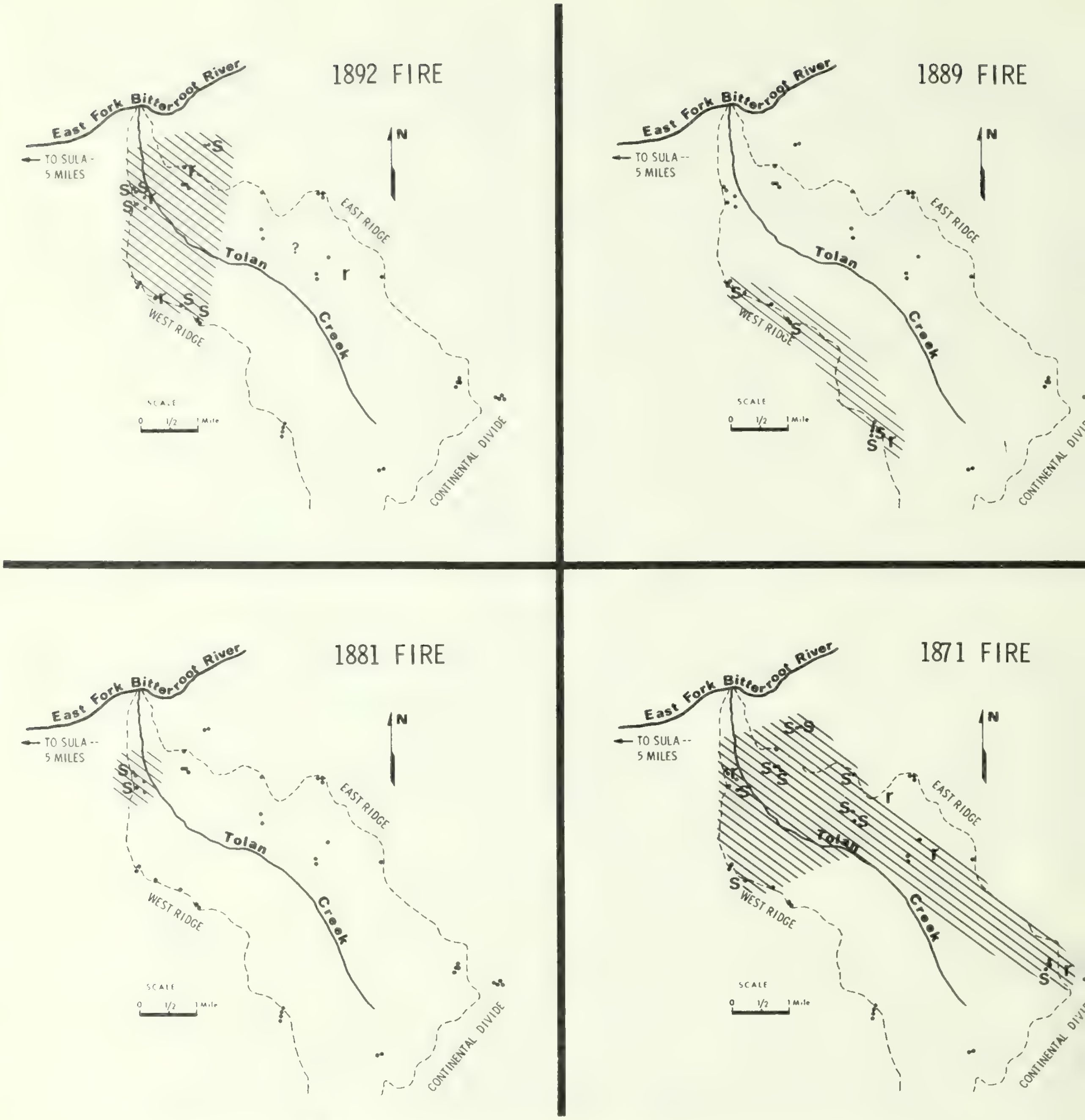


Figure 11.--Maps showing the apparent extent of fires by year on a study area.
• = sample trees, s = scar on that tree that year, r = regeneration from that fire detected in that stand.

INTERPRETATIONS

By inspecting the results of these various analyses, the investigator can summarize fire frequencies for both the "historic" and "suppression" periods by habitat types. He can document effects of natural fire on forest composition and stand structure by habitat type (columns 4 and 5, table 4). Using current timber type (timber inventory) and habitat-type information, he can estimate the probable effects of current fire management on forest composition, stand structure and, possibly, fuel accumulations. Considering fire frequencies and relating the maps of historic fires to the surviving tree growth as well as to age-class information in general, he can interpret relative fire intensities experienced in the various stands and habitat types. Stand-destroying fires, for instance, will be obvious from age-class data, since no surviving trees are to be found except for widely scattered veterans that generally have a scar dating to that fire. Maximum historic intervals between natural fires can be compared with intervals during the suppression period to judge ecological implications.

This information on fire history and vegetation can be correlated with fuel inventories, insect and disease information, wildlife-habitat trends, etc., to estimate the effects of various types of fire management practices. Thus, these findings should also help in selection of reasonable goals and methods for fire and fuel management.

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CONTENTS

Page

INTRODUCTION 1

FIRE USE PLANNING 1

THE FIRE USE PLAN AND REPORT 2

Part 1--Treatment Area and Objectives 3

1.1 Purpose of Plan 3
1.2 Treatment Area 3
1.3 Land Management objectives 3
1.4 Treatment Constraints 4
1.5 Treatment Objectives 4
1.6 Treatment Alternatives 4

Part 2--Fire Prescription 4

2.1 Treatment Specifications 4

2.11 Desired accomplishment 4
2.12 Desired fire behavior 4
2.13 Required environmental conditions 5

2.2 Treatment strategy 5
2.3 Preburn Monitoring 5
2.4 Evaluation 5

Part 3--Burning Plan 5

3.1 Preparation for Burning 5
3.2 Preburn Monitoring 5
3.3 Ignition 6
3.4 Holding 6
3.5 Mopup 6
3.6 Evaluation 6
3.7 Cost Summary 6

Part 4--Report 6

4.1 Accomplishment 6
4.2 Fire Behavior 6
4.3 Environmental Conditions 7
4.4 Cost 7
4.5 Observations and Recommendations 7

SUMMARY 7

PUBLICATIONS CITED 8

APPENDIX 9

Fire Use Plan and Report for Burnt Mountain Wildlife Burn
Spring 1978 9

RESEARCH SUMMARY

To implement the concept of fire management and provide a standard terminology, this paper proposes a standard fire use plan and report format.

A successful prescribed fire is described as one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved. The following information is required for fire use planning:

1. Physical and biological characteristics of the site to be treated.
2. Land and resource management objectives for the site to be treated.
3. Known relationships between preburn environmental factors, expected fire behavior, and probable fire effects.
4. The existing art and science of applying fire to a site.
5. Previous experience from similar treatments on similar sites.

The fire use plan and report format has four parts. In Part 1, Treatment Area and Objectives, the planner states the purpose of the plan; describes the physical and biological characteristics of the site; and identifies land management objectives, treatment constraints, treatment objectives, and treatment alternatives.

The information assembled in Part 1 is used to write Part 2, Fire Prescription. The planner defines the results desired, the desired fire behavior, and the condition under which the fire must burn. He is further asked to describe treatment strategy, preburn monitoring needs, and how the fire will be evaluated.

The Burning Plan, Part 3 of the plan, is based on Part 2 and is the action plan. The planner must specify all the tasks involved in the preparation for burning, preburn monitoring, ignition, holding, mopup, and evaluation. For each task identified, the plan should tell when and how it will be done and who will do it.

Part 4 is the Report. It is designed to evaluate the plan in terms of the fire and its effects. Information requested concerns the actual accomplishment by the fire, the actual fire behavior, the environmental conditions under which the fire burned, and the cost. Observations and recommendations are also requested.

INTRODUCTION

A new philosophy called "fire management" (Moore 1974; DeBruin 1976; Kilgore 1976) has changed the attitudes of many natural resource managers toward fire protection and use. A generally accepted definition of fire management does not exist although several have been suggested (Barney 1975; Simard 1976). Fire management is difficult to define because the term is used to represent both a land management philosophy and a land management activity. As a management philosophy, fire management suggests that fire, in an ecological sense as well as a protection sense, should be considered when developing land and resource management objectives and that, once these objectives have been set, fire-related activities should be designed to support their accomplishment. As a land management activity, fire management includes all the tasks related to the protection of forests from unwanted fire, the use of fire to accomplish management objectives, and the inclusion of fire considerations in land and resource management plans.

The purpose of this paper is to propose a fire use plan and report format to implement the concept of fire management and to provide a standard terminology. For example, the terms "fire prescription" and "burning plan" are often used as synonyms. In the proposed format these terms have very specific and different meanings. This paper lists the elements that should be considered when planning fire use. It does not tell how detailed the information relating to these elements needs to be. The required resolution and precision of needed information should be specified in prescribed fire guidelines. The guidelines can be written for local or regional areas or for individual vegetative types. The fire use planning format proposed here can be used as an outline for the organization and content of such prescribed fire guides.

FIRE USE PLANNING

From a fire management perspective, a successful prescribed fire is one that is executed safely, burns under control, accomplishes the prescribed treatment, and attains the land and resource management objectives for the area involved. Successful prescribed burning requires planning. Such planning should be based on the following factors:

1. Physical and biological characteristics of the site to be treated.

2. Land and resource management objectives for the site to be treated.

3. Known relationships between preburn environmental factors, expected fire behavior, and probable fire effects.

4. The existing art and science of applying fire to a site.

5. Previous experience from similar treatments on similar sites.

The proposed fire use plan is designed to direct the prescribed fire planner through the above factors in a logical sequence. The proposed report is designed to provide a written record of actual prescribed burning experience that the planner can use when writing subsequent plans. The actual form of the resultant plan is left to the judgment of the planner or to the needs of his employer. Some prefer fill-in-the-blank plans while others favor narrative plans that vary according to the complexity of the planned fire. The primary concerns here are the thought process involved in planning fire use and the technical validity of the plan produced. One final point before considering the proposed format: it is assumed the decision to use fire has already been made. It is further assumed the decision to burn is compatible with land and resource management objectives for the area and these objectives are defensible from an ecological standpoint.

THE FIRE USE PLAN AND REPORT

The fire use plan and report format is in four parts. The first part deals with the planned fire treatment and the site to be treated. The prescribed fire planner is asked to describe the biological and physical characteristics of the site and to define the treatment objectives in terms of land and resource management objectives. The planner is also asked to identify all constraints that bear upon how prescribed fire can be applied to the area.

The information assembled in Part 1 is used to write the fire prescription, which is Part 2 of the proposed format. The first step in writing a fire prescription is to further define the treatment objectives in terms of the type and amount of work the fir must do. This is a critical task in the planning process. How well the fire accomplishes the desired work becomes the measure by which success or failure of the prescribed fire will be judged. Once the fire's work has been specified, the planner must draw upon existing knowledge of fire behavior and fire effects to determine (1) the type of fire behavior desired, (2) the environmental conditions under which the fir is likely to behave as desired, and (3) the burning techniques that must be used to get fire to behave as desired under these environmental conditions.

The burning plan, Part 3 of the proposed format, is based upon the fire prescription. The burning plan is the action plan, or project work plan, for a prescribed fire It translates the fire prescription into on-the-ground tasks that must be performed before, during, and after the fire. For each task identified, the plan should tell whe and how it will be done and who will do it. The needed equipment and supplies are listed and the cost of the project is determined. A properly prepared burning plan becomes the only document needed by the people responsible for conducting the planned prescribed fire.

Part 4 of the report is designed to evaluate the plan in terms of the fire and its effects. The purpose of this evaluation is to provide information for future fire use planning efforts. Too often such information is lost or only partially used by prescribed fire planners. Prescribed fire planners should keep a file of those reports indexed appropriately for fast retrieval, and use them as a tool for fine-tuning subsequent fire prescriptions and burning plans. Fire information systems such as FIREBASE (Taylor and Eckels 1977) might be used to store and retrieve such information.

An expanded outline of the proposed fire use plan and report format follows:

Part 1 — Treatment Area and Objectives

1.1 *Purpose of Plan*--State briefly and in general terms the type of treatment planned and its purpose. For example:

- --prescribed broadcast fire for hazard reduction and site preparation on a 35-acre (14.2-hectare) clearcut unit containing larch/fir logging slash
- --prescribed broadcast fire for elk winter range improvement on a 500-acre (202.3 hectare) low elevation mountain shrubland
- --prescribed broadcast fire for rejuvenation of 350 acres (141.6 hectares) of little bluestem grassland.

The only purpose of this statement is to identify the type of activity being planned. Such a statement would logically follow the decision to use fire, which has already been made.

1.2 *Treatment Area*--Identify and describe the physical and biological characteristics of the area to be treated. Use maps, graphs, tables, etc., to show:

- --size of area
- --location
- --elevation
- --landforms (slope and aspect)
- --soil types (erodibility, susceptibility to damage)
- --vegetation (species, cover types, habitat types)
- --down and dead fuels (amount, size class distribution, depth, continuity, etc.)
- --climate and weather patterns (seasonal averages, probability of occurrence of different weather patterns, etc.)
- --wildlife and wildlife habitats.

Information on the above items often exists in ready to use form in land management plans, environmental statements and reports, resource management plans, and summaries of land and resource inventories.

1.3 *Land Management Objectives*--Summarize, very briefly, the land and resource management objectives and management guidance for the area to be treated. Refer to appropriate land management plans, resource management plans, silvicultural prescriptions, fire management plans, and other sources. For example (USDA Forest Service 1977):

> *Management Objectives*--The management objectives for the National Forest land within this management unit are to (1) protect the aquatic environment by maintaining water quality for onsite and offsite use, (2) maintain the visual quality of the unit as reviewed from the major travel routes, and (3) manage the timber resource to maintain a healthy, productive forest within constraints imposed by watershed and visual concerns.
>
> *Management Guidance (National Forest Land)*--Slash disposal will be complete enough to provide for free movement of wildlife through the management unit. Generally this means that slash concentrations more than 1-1/2 feet deep must be eliminated.

1.4 *Treatment Constraints*--Identify and define all constraints that bear upon how treatment can be applied. Consider:

--environmental constraints (air quality, water quality, accelerated erosion)
--multiple use constraints (protection of other uses, resource management trade-offs)
--economic constraints (maximum cost/acre)
--operational constraints (access, terrain, manpower, etc.)
--administrative constraints (agency policy, rules, etc.)
--legal constraints (State fire laws, forest practice acts, etc.).

Constraints are usually identified in the land management plan for the area to be treated. Other sources are agency rules, regulations, and policy; State and Federal laws; production rates and operational capabilities of men and machines; and project budgets.

1.5 *Treatment Objectives*--State in terms of land or resource management objectives referred to in section 1.3 and any constraints listed in section 1.4. For example:

--reduce potential rate-of-spread to "low," provide for free movement by wildlife, regenerate area naturally with 1,000 western larch seedlings per acre.
--increase the amount of redstem ceanothus on the area, rejuvenate decadent shrubs to make them more available and palatable for elk, and set back conifer encroachment.

1.6 *Treatment Alternatives*--Identify acceptable alternatives to the use of fire, if this was not done preceding the decision to use fire. State why they were not chosen.

This information can be important under certain circumstances whereby the manager must set priorities for burning because of time or manpower constraints. For example, the prescribed burning season might be shorter than expected due to persistence of adverse summer burning conditions into the fall. In such a situation, efforts can be concentrated on burning those areas for which no acceptable nonfire alternative exists.

Part 2 — Fire Prescription

2.1 *Treatment Specifications*

2.11 Desired accomplishment--*State, in precise terms, the work the fire needs to do*, i.e.:

--inches or percent of duff to be removed
--amount or percent of fuels to be reduced by size class
--amount or percent of mineral soils to be exposed
--vegetation to be killed or otherwise treated by species.

2.12 Desired fire behavior--Define the kind of fire needed to accomplish desired work while complying with any treatment constraints listed in 1.4, i.e.:

--rate-of-spread (fast or slow--specify acceptable range)
--fire intensity (hot or cool--specify acceptable range)
--flame height (especially if burning under a timber stand)
--flame length.

To obtain this information, use prescribed fire guidelines, fire models, fire effects literature, consultation with experts, etc.

2.13 Required environmental conditions--Define the conditions, or range of conditions, necessary to obtain the desired fire behavior and effects. Use prescribed fire guidelines, fire models, consultation with experts, etc. Consider:

--fuel moistures
--duff moisture
--windspeed and direction
--soil moisture
--temperature
--relative humidity
--physiological condition of vegetation (cured, dormant, etc.)

2.2 *Treatment Strategy*--Describe the sequence of events needed to achieve the treatment objectives and identify the tasks necessary for success:

--preburn tasks (slashing, snag felling, fireline construction, etc.)
--ignition technique (strip headfire, center fire, etc.)
--ignition methods (remote, drip torch, grenades, etc.)
--firing pattern or sequence.

2.3 *Preburn Monitoring*--Briefly describe how the area will be monitored to decide when conditions, specified above in 2.13, are correct for burning. Indicate the measurements to be taken, where they will be taken, and the precision needed. Consider the need for fuels inventory, fuel and duff moisture measurements, weather measurements, etc.

2.4 *Evaluation*--briefly describe how the treatment area will be evaluated to determine if treatment objectives, specified above in 2.11, were met. Specify measurements to be taken during the fire to evaluate fire behavior and measurements to be taken after the fire to evaluate fire effects.

Part 3 — Burning Plan

3.1 *Preparation for Burning*--For each preburn task identified in 2.2 of the prescription, specify:

--what will be done
--when it will be done
--how it will be done
--who will do it
--equipment and supplies needed
--cost.

3.2 *Preburn Monitoring*--For each monitoring task identified in 2.3 of the prescription, specify:

--what will be done
--when it will be done
--how it will be done
--who will do it
--equipment and supplies needed
--cost.

3.3 *Ignition*--On a map of the area to be burned, indicate ignition plan. Show sequence of ignition, placement of ignition crew, kind and location of ignition devices, etc., specify:

--what will be done
--when it will be done
--how it will be done
--who will do it
--equipment and supplies needed
--cost.

3.4 *Holding*--Indicate on a map of the burn area placement of men and equipment for holding fire in planned area. Indicate how escapes will be dealt with, specify:

--what will be done
--when it will be done
--how it will be done
--who will do it
--equipment and supplies needed
--cost.

3.5 *Mopup*--Describe plans or mopup and/or patrol after the fire has been conducted, specify:

--what will be done
--when it will be done
--how it will be done
--who will do it
--equipment and supplies needed
--cost.

3.6 *Evaluation*--For each evaluation task listed in 2.4 of the prescription, specify:

--what will be done
--when it will be done
--how it will be done
--who will do it
--equipment and supplies needed
--cost.

3.7 *Cost Summary*--Summarize planned costs for manpower, equipment, and supplies.

Part 4 — Report

4.1 *Accomplishment*--State in precise terms the actual accomplishment of the fire. For example, 3 inches (7.6 cm) of duff removed; 20 percent of area bare to mineral soil. Relate this to the desired accomplishment listed in 2.11 of the fire prescription.

Timing of fire effects evaluation is important. Some effects are apparent immediately after the fire and should be evaluated within a week. Other effects might not be apparent until the start of the subsequent growing season. In such situations, the report should be revised to include the longer term effects after they have been evaluated.

4.2 *Fire Behavior*--State the actual fire behavior that occurred. Relate this to desired fire behavior described in 2.12 of the fire prescription. Quantify, if possible.

.3 *Environmental Conditions*--State the actual fuel moisture, weather conditions, and other designated environmental factors that preceded the fire and that occurred during the fire. Relate to those specified in 2.13 of the fire prescription.

.4 *Cost*--State actual costs incurred. Explain any differences from estimated costs.

.5 *Observations and Recommendations*--Summarize significant aspects of the fire in relation to expectations. Relate what actually happened to what was expected to happen. Indicate knowledge gained that should be considered when planning subsequent prescribed fires, for example (Norum 1975):

> Experience gained during this fire indicates a need to modify the ignition procedure for future hazard reduction burns in this fuel type. Because of the concentrated and discontinuous nature of the fuels, fires ignited across the lower edge of a plot often burned vigorously until a fuel discontinuity was reached, whereupon the fire went out. The result was a very ragged burn with hazardous fuel left in the center of the unit. Control and containment difficulties were experienced when ground fuels were sufficiently dry to carry fire between concentrations. Crown fires began to increase in frequency, and spotting outside of the prescribed area required alert patrol and vigorous suppression. Based on the results of this experience, I suggest ignition of strips of fuel across the slope, beginning at the upslope perimeter and progressing to the bottom of the plot. Permit each strip of ignited fuel to burn until the level of maximum intensity passes, then ignite the next downslope and adjacent strip. This procedure should assure ignition of all fuels and minimize control problems.

SUMMARY

A successful prescribed fire is one that safely and efficiently achieves the land and resource management objectives for which it was conducted. Such fires do not happen by accident; they are the result of careful and intelligent planning.

To plan a successful prescribed fire the planner must clearly define why he wants to burn a site and what he hopes to accomplish. He must also describe the physical and biological characteristics of the site to be treated. He must then blend this information with an understanding of the relationships between fuel, weather, topography, fire behavior, fire effects, and burning techniques. Finally, the actual fire must be evaluated in order to improve the performance of subsequent plans.

A fire use plan and report format is presented to guide the prescribed fire planner through the important steps for planning successful fire use. At the heart of this proposed planning format is the fire prescription, which tells what kind of fire is needed and identifies the conditions under which it must burn, and the burning plan, which tells how the prescription will be carried out on the ground.

A fire use plan for a planned prescribed fire on the Lolo National Forest is included as an appendix. This plan was written by a fire manager using the format proposed in this paper.

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APPENDIX

Fire Use Plan and Report for Burnt Mountain Wildlife Burn

Spring 1978

John Roberts

Fire Management Officer

Lolo National Forest

Missoula Ranger District

Part 1 – Treatment Area and Objectives

1.1 PURPOSE OF PLAN

This project is a prescribed broadcast fire for habitat improvement on elk and mule deer winter and spring range.

1.2 TREATMENT AREA

a. Size of area. The treatment area contains 160 acres (64.75 hectares), of which 135 acres (54.6 hectares) will be burned.

b. Location. The treatment area is located at the head of Babcock Creek just east of Burnt Mountain in the south half of Section 28 and the southwest corner of Section 27, T11N, R16W. Access is by the Gillispie Creek Road #354.

c. Elevation. The treatment area extends from 5300 feet (1615 meters) on the bottom to 6385 feet (1946 meters) at the top.

d. Landforms. The slope of the area averages 30 percent or more and is mostly a southerly aspect.

e. Soil type. The area is comprised of loamy grassland soils which are mainly bedrock of quartzites and argillites. These soils are well drained with moderate to moderately rapid permeability and have no ash mantle. Surface erosion is low. They have a history of persistent grassland and meadow vegetation.

f. Vegetation. This particular area falls into the Ponderosa pine/Douglas fir savanna habitat group. The principal habitat type within this group is Douglas fir/Fescue (both Rough and Idaho). An analysis of the transect showed the following vegetation:

Fescue - 38%
Strawberry - 8%
Lupine - 16%
Other - 16%
Chickweed - 14%
Prairiesmoke - 4%
Pussytoes - 4%

g. Down and dead fuels. Total fuel loading is estimated at less than 10 tons/acre (2.24 kg/m^2). This is mostly dead grass and forbs, with a scattering of tree needles and small dead twigs and limbs.

h. Climate and weather patterns. The Burnt Mountain area is located within a rain shadow of the Sapphire Mountains and receives approximately 21 inches (53.3 cm) of moisture per year. This occurs mainly in the form of snow. Almost all weather in the area is from the west with occasional storms coming from the northeast and east. These high wind storms from the northeast occur mostly in the fall and winter. The proposed burn time is planned for the spring, and adverse winds are not expected to be a problem. Early spring weather data is not available for the fire area or vicinity. Records are available from the now-defunct Bonita weather station (elevation 3544 feet or 1080 meters) for the period 1954-1968. Analysis of these records show the following 10-day means:

10-DAY MEANS FOR SELECTED WEATHER VARIABLES,

BONITA RANGER STATION, 1954-1968.

Weather Parameter	Period			
	May 1-10	May 11-20	May 21-31	June 1-10
Max. Temp. (°F)	62.7	66.8	70.1	70.5
Range	49.9-79.0	58.0-76.3	63.3-78.5	62.8-79.9
Min. Temp. (°F)	33.3	34.3	38.7	41.3
Range	26.1-40.8	30.1-41.1	34.5-44.3	36.4-47.7
4 p.m.(MST) Temp. (°F)	58.0	62.6	64.7	65.7
Range	46.4-76.3	54.3-73.4	55.7-73.2	58.4-75.1
4 p.m.(MST) RH (%)	42.9	37.1	42.6	45.3
Range	16.2-64.8	22.6-57.7	32.7-59.3	27.2-65.6
4 p.m.(MST) Wind (mi/h)	6.9	6.0	6.2	6.2
Range	3.8-13.9	4.0-9.6	2.8-12.2	2.5-9.8

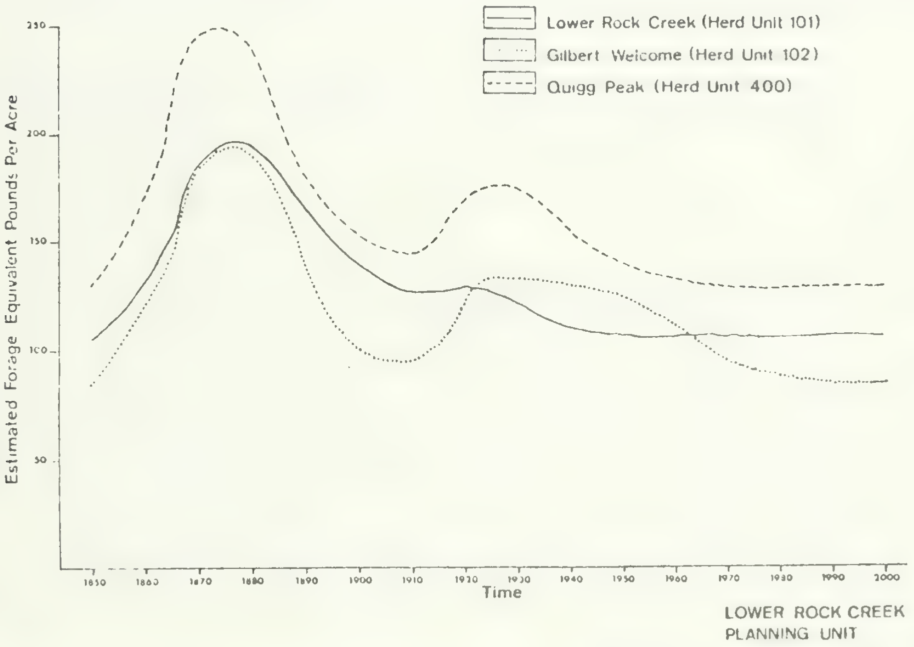

Figure 1.--Estimated pounds of deer-elk winter forage per winter range acre for three winter range units over a 150-year period.

i. Wildlife and wildlife habitats. The proposed burn is located within deer and elk winter range and is designed to increase forage production. The Burnt Mountain area falls within the lower Rock Creek herd unit. According to the Background Information Packet and Management Alternatives for the Lower Rock Creek Planning Unit (USDA Forest Service 1977), the area produced an estimated 200 pounds per acre (224 kg/ha) of deer and elk forage during the 1880's and has been on a steady decline since that time as shown in figure 1. The area now produces about 110 pounds of deer and elk forage per acre (123 kg/ha). This lower production rate is at least partially due to the fact that the area has not burned since before 1900.

1.3 LAND MANAGEMENT OBJECTIVES

The treatment area is identified as deer and elk winter range in the land use plan for the Lower Rock Creek Planning Unit. The management objectives for this area are to: (1) maintain the deer and elk habitat consistent with the needs of existing populations using the area, and (2) maintain naturally existing water quality.

A synopsis of the management guidance for the area follows:

1. Timber harvest and prescribed fire are methods which may be used to maintain the deer and elk winter range in a successional stage compatible with winter range management objectives.

2. Timber harvest will be directed toward maintenance and improvement of the deer/elk winter range.

3. Management activities will be modified as necessary to assure protection of the soil and water resources in areas with sensitive soils.

4. Management activities will follow the guidelines of the Modification Visual Quality Objective. (See Appendix in Lower Rock Creek Planning Unit, USDA Forest Service 1977.)

5. Slash disposal will be complete enough to provide for free movement of deer and elk through the management unit and to prepare sites for natural regeneration of browse plants.

6. Motorized vehicles will not be allowed in this management unit during the winter months.

7. If conflicts between cattle and big game become apparent in the future, the conflict will be resolved in favor of big game.

8. Immediate action will be taken to suppress wildfire. If fires are not controlled by initial attack forces, further control efforts will be determined on a case-by-case basis using guidelines contained in the fire management plan for the area. The guidelines will consider the management objectives of the management unit.

1.4 TREATMENT CONSTRAINTS

The following constraints govern the use of fire on the treatment area:

a. Environmental constraints.

(1) Air quality.

(a) Fuel moisture requirements should be such that ragged, long-smoldering fires do not occur.

(b) The burning period should be from early to midafternoon to facilitate smoke dispersion.

(c) At upper elevations (like this burn will be), very strong winds should be avoided as they tend to flow up and down the terrain intersected.

(2) Water quality.

The management objective for the treatment area (as outlined in the Lower Rock Creek Planning Unit, USDA 1977) calls for maintaining naturally existing water quality. This means that the water quality should not drop below a rating of "$B-D_1$" classification under Montana water quality criteria.

(3) Soil.

The management guidance for the Lower Rock Creek Planning Unit says that management activities will be modified as necessary to assure protection of the soil and water resources in areas with sensitive soils.

b. Multiple use constraints.

The treatment area is within the Spring Creek cattle allotment; and it also falls within the Visual Resource category of common landscape, seldom seen or not visible with modification permitted. (See visual resource map, Lower Rock Creek Planning Unit, USDA.)

c. Economic constraints.

A maximum of $750 is available for this project.

d. Operational constraints.

There will be no equipment other than hand-held used in conjunction with the burn.

e. Administrative constraints.

Escaped fire, as determined by the District Fire Management Officer, will be suppressed as per management guidance found in the Lower Rock Creek Planning Unit.

f. Legal constraints.

There are no legal constraints on the proposed burn area. It is just outside of Missoula County; therefore, no county burning permit is necessary. A courtesy call to the Missoula County Airshed Group may be in order, because the area is close to the county line.

1.5 TREATMENT OBJECTIVE

The primary objective of the fire is to increase the overall production of desirable forage on the area by: (a) increasing the production of forage and legumes, and by (b) improving the palatability of the fescue bunchgrass. Accomplishment of this objective will improve the area's capability to produce more deer and elk by providing more protein during the late spring and early summer--a critical factor for successful fawn and calf survival.

1.6 TREATMENT ALTERNATIVES

The alternatives to burning are:

a. Modify the area silviculturally through tree harvest. This could have the effect of increasing the size of the area slightly but may be offset by the disturbance caused from logging (invasion of weeds and the slow recovery of grasses on the bared soil). In this area, tree cutting is not an acceptable alternative because nearby areas have been cut so heavily that additional harvest may cause watershed damage.

b. Permit the cattle on the Spring Creek allotment to graze the area heavily enough to produce bare mineral soil for germination of forbs, or legumes This is not desirable because the effect would take longer than one year to accomplish and could promote the spread of weeds and increase the risk of surface erosion. Also, it is doubtful that the cattle could be held on the area long enough to produce the desired results.

PART II - FIRE PRESCRIPTION

2.1 TREATMENT SPECIFICATIONS

2.11 Desired Accomplishment

The fire should burn all of the dead bunchgrasses to within 1/2 inch (1.3 cm) of the root crown. Any other grasses, forbs, or legumes should be burned off at or near ground line. This will have the effect of producing approximately 30-40 percent bare mineral soil which would, in turn, improve germination conditions to permit increased forb and legume production. The woody fuels are scattered and discontinuous, and their consumption by the fire is desirable but not necessary.

2.12 Desired Fire Behavior

A relatively hot fire (remembering that fuels are less than 10 tons/acre or 2.24 kg/m^2) moving fast enough to consume all dead grass is required. Fuel moisture should be about 13 percent for the light fuels to assure good combustion and lessen the chance for smoldering fires. To obtain the best conditions, the burn should start between 11:00 a.m. and 1:00 p.m.

2.13 Required Environmental Conditions

Based upon the results obtained in Mormon Creek on a similar habitat type during the spring of 1977, the following conditions should be adhered to for best results.

Fuel moisture content for dead grass should not exceed 13 percent. Soil moisture content should not exceed 45 percent nor be lower than 25 percent. Windspeed can be up to 20 mi/h (32.2 km/h) with no problems, but ideal is 8-12 mi/h (12.9 - 19.3 km/h). Wind direction is no problem, just so it is steady from one direction. Normal wind direction is out of the southwest and up canyon.

Air temperature should be 50°F (10°C) in order to dry the grass to the desired moisture content. From 45° to 65° (7.2° to 18.3°C) would be within range to produce the desired effects.

Relative humidity should be between 35 and 45 percent, with 40 percent and falling being ideal. It is imperative that the bunchgrasses be cured. The cured condition is necessary to carry the fire, to produce bare mineral soil, and to release the nutrients necessary to stimulate the vegetation.

Percentage frequency of occurrence for the combination of weather parameters indicated in this prescription is about 16 percent during the period May 1 through June 10. This is based on 1954-1968 weather records from the Bonita Station. This figure does not reflect the occurrence of favorable prescription conditions prior to May 1.

The chance of obtaining favorable conditions decreases as season progresses as indicated below:

PERCENTAGE FREQUENCY OF OCCURRENCE FOR PRESCRIPTION

WEATHER CONDITIONS FOR THREE LEVELS OF WINDSPEED

Windspeed (mi/h)	May 1-10	May 11-20	May 21-31	June 1-10
5-9	10.7	14.6	8.3	7.4
10-14	9.3	3.1	2.8	2.7
15-19	3.1	0.8	0.7	1.4
Overall	23.1	18.5	11.8	11.5

2.2 TREATMENT STRATEGY

Preburn tasks - One trip into the area for final scouting and layout will be necessary. This can be incorporated into the fuel sample collection to determine moisture content. No slashing, snag felling, or fireline construction is necessary.

Ignition technique - Strip head firing will be used to burn the area. Smaller strips of about 5 to 10 feet (1.5 to 3.0 meters) will be used at the top to keep the burn within the unit. As the strips get to the road boundary (see map), they should be widened to 15 to 30 feet (4.6 to 9.1 meters) or more depending on fine tuning of the fire.

Ignition methods - Drip torches will be used (three of them).

Firing pattern - Strip head firing will be used starting at the east end of the block (see map, fig. 2) with the torchman starting across one at a time.

PROPOSED BURNT MOUNTAIN WILDLIFE BURN

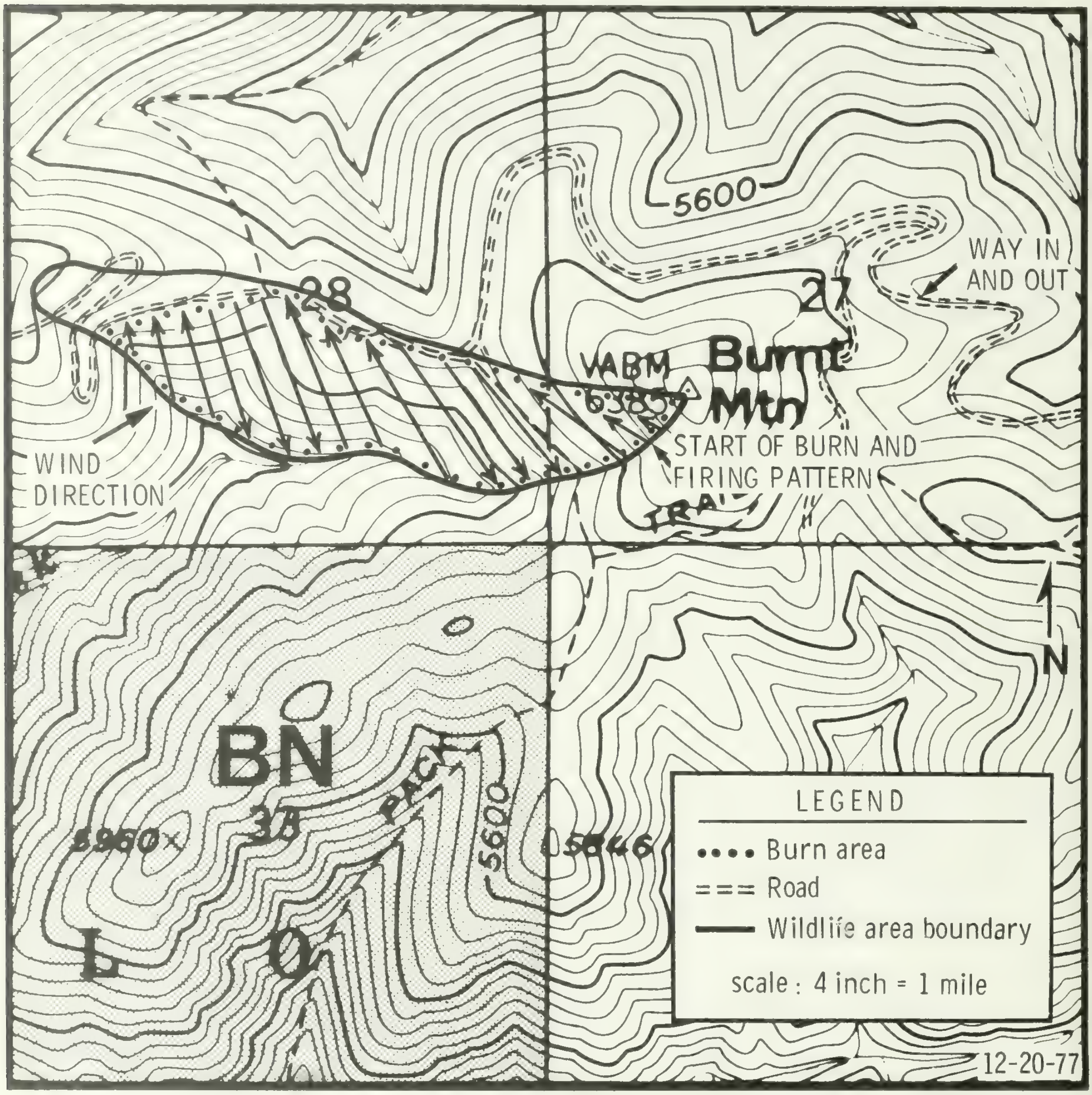

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Figure 2

2.3 PREBURN MONITORING

Some monitoring will be necessary to determine if all snow is off the proposed burn area. This can be accomplished by driving up Rock Creek approximately 7 miles (11.3 km) to the mouth of Babcock Creek and looking up the creek toward Babcock Mountain to see if it is bare. If it is bare, then the Burnt Mountain area will also be bare. Once the area is free of snow, two days of sunshine with temperatures of 45°F (7.2°C) or more should pass before fuel and soil moisture samples are taken. Two samples each of bunchgrasses and soil should be taken at the top, middle, and bottom of the area to obtain an average fuel moisture and soil moisture percent.

When sampling the bunchgrasses, each individual clump will constitute a sample. All of the clumps will be cut as close to the ground as possible. The soil samples will extend to a depth of 4 inches (10.16 cm).

After collection, all samples will be weighed and ovendried, and moisture contents calculated. Relative humidity, wind direction and speed, and air temperature will also be taken in conjunction with fuel and soil samples. All of the samples will be taken as near to the planned hour of ignition as possible. This will probably figure out to a burn time of 11:00 a.m or slightly later.

2.4 EVALUATION

A permanent transect has been run through the area; and species composition, total pounds of forage, and percent of green vegetation have been calculated. Following the burn, this transect will be rerun in late June; and measurements will be taken to determine success of the burn in reducing the grass cover and exposing mineral soil.

PART III - BURNING PLAN

3.1 PREPARATION FOR BURNING

Four men will burn the area. These four men will do the final scouting and layout and will be familiar with the objectives of the burn and how it will be conducted. The final scouting and layout will be done when fuel and soil samples are collected to determine moisture content. The District Fire Management Officer will determine when the area is snow free. He will also act as burning boss and be one of the four men on the fire.

The following equipment is needed for the fire:

1. 2 4x4 1/2-ton pickups
2. 2 2-man snowmobiles and equipment
3. 6 drip torches filled at station
4. 10 gallons of extra drip torch fuel
5. fuel sampling kit
6. 4 personal portable radios
7. camera and film (35mm)
8. belt weather kit (don't forget vial of distilled water)
9. necessary forms and scratch paper
10. shovel and pulaski for each person
11. portable dictaphone machine.

The District FMO has the responsibility for the burn, seeing to the equipment, and keeping an accurate account of project costs.

3.2 PREBURN MONITORING

This includes determining when the area is ready for collection of fuel samples and when moisture content and weather conditions meet the prescription. These items are the responsibility of the District FMO. The FMO will also keep current with the weather forecast. This will be handled by phone calls to the local weather bureau. It may be necessary for an on-the-spot forecast, but most likely the weather will be a high pressure system which presents no problems.

3.3 IGNITION

Given the normal wind conditions (southwesterly and up-canyon winds), burning will start in the far east corner of the area at the top of Burnt Mountain. There will be three torchmen. The first torchman will fire out the corner. The second will strip head fire behind the first after the first man has completed his strip. The third man will start after the second has completed his strip. Once the three torchmen have completed their first strip, they will continue following the same lighting pattern until all of the block is burned. The firing pattern and burn area should be the same as that shown on the accompanying map.

Following is the necessary equipment for ignition:

1. 6 drip torches filled at the Ranger Station
2. 10 gallons of drip torch fuel
3. 4 personal portable radios
4. 35mm camera and film
5. portable dictaphone machine.

It is the responsibility of the District FMO to keep accurate cost records for the entire operation.

3.4 HOLDING

No holding is necessary. The burn will take place when the surrounding aspects still have sufficient snow to stop a ground fire. No equipment or supplies will be necessary for holding.

Escapes are not expected to be a problem because of the time of the year and the habitat type. Should any serious escapes occur (potential crowning in adjacent areas), they will be suppressed as rapidly as possible.

3.5 MOP-UP

No mopup will be planned, because the fuels are 1 inch or less in diameter and will not "lay over." No equipment or supplies are necessary for mop-up.

3.6 EVALUATION

During the burn, the District FMO will use the portable hand dictaphone to record the fire behavior, fire strategy, and preliminary treatment success. The permanent transect that was established in the late summer of 1977 must be reread during the latter part of June 1978 to ascertain the results of the burn. The following information must be calculated: (1) pounds of deer and elk forage/acre and also total pounds of forage/acre--this will be used to calculate the effectiveness of the burn, (2) available, usable forage for deer and elk, (3) percent of ground cover, (4) species variety.

The evaluation of the area will be done through the District Resource Assistant. He will furnish a competent person and the equipment necessary to do the job and make the calculations. Any help needed by the Resource Section will be furnished by Fire Management through the District FMO. The cost of the evaluation will be borne by Fire Management.

3.7 COST SUMMARY

Total cost of the project is estimated at $562. This is broken down as follows:

1. manpower - 8 man-days at $60.00/day = $480.00,
2. equipment use - 300 miles at $0.19/mile = $57.00,
3. drip torch fuel - 10 gallons at $0.50/gallon = $5.00,
4. miscellaneous = $20.00.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Field programs and research work units are maintained in:

- Billings, Montana
- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)
- Reno, Nevada (in cooperation with the University of Nevada)

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Fischer, William C.
1978. Planning and evaluating prescribed fires--a standard procedure. USDA For. Serv. Gen. Tech. Rep. INT-43, 19 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Provides a standard format and checklist to guide the land manager through the important steps for prescribed burning. Describes the kind of information needed to prepare fire prescriptions and burning plans. Identifies the elements of a fire prescription, a burning plan, and a prescribed fire evaluation. A plan written for an actual prescribed burning is included as an appendix.

KEYWORDS: wildland management, fire management, prescribed fire, fire management planning.

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VEGETATIVE PROPAGATION OF ROCKY MOUNTAIN ASPEN

George A. Schier

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General Technical
Report INT-44
INTERMOUNTAIN FOREST
AND RANGE
EXPERIMENT STATION
FOREST SERVICE
U.S. DEPARTMENT OF
AGRICULTURE

THE AUTHOR

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USDA Forest Service
General Technical Report INT-44
August 1978

VEGETATIVE PROPAGATION of ROCKY MOUNTAIN ASPEN

George A. Schier

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401

CONTENTS

Page

INTRODUCTION 1

CLONE SELECTION 1

ROOT COLLECTION 2

ROOT PREPARATION 3

SUCKER PROPAGATION 4

ROOTING SUCKER CUTTINGS 6

CULTIVATING ROOTED CUTTINGS 9

OUTLINE--VEGETATIVE PROPAGATION PROCEDURES 11

PUBLICATIONS CITED 12

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RESEARCH SUMMARY

Described in detail are the author's procedures for vegetatively propagating aspen (Populus tremuloides Michaux). The procedures are an adaptation of Larsen's original methods. Roots are taken from clones having desirable phenotypic characteristics. Segments are treated with a fungicide, their ends are sealed with paraffin, and they are planted in moist vermiculite. Suckers develop within 6 weeks. The bases of sucker cuttings are treated with indolebutyric acid (IBA) and inserted in a moist vermiculite:perlite medium. Cuttings are rooted under an intermittent mist or in a high-humidity, polyethylene chamber. Well-developed root systems develop in 2 to 3 weeks. Rooted cuttings are planted in containers with a peat moss:vermiculite mixture and fertilized with a complete fertilizer. Supplemental lighting can be used to extend the growth period. Chilling requirements of the cuttings are satisfied by natural cold during winter months or by storage in a cold room. In the spring, dormant cuttings are outplanted or transferred to large pots. Aspen shows considerable clonal variation in suckering and rooting ability.

INTRODUCTION

Quaking aspen (*Populus tremuloides* Michaux) has become a popular ornamental tree in the Rocky Mountain region. There is also a great deal of interest in planting aspen on wild lands to restock deteriorating natural stands and to revegetate strip mines in areas where aspen originally grew. Wildlings have been successfully used in landscaping. However, a large-scale nursery system will be necessary to meet increasing demands for aspen planting stock.

Because aspen is a highly variable species, it is usually propagated asexually so that the unique characteristics of desirable genotypes are reproduced. In comparison to the relatively high rooting ability of stem cuttings from the closely related balsam (for example, *P. balsamifera* and *P. trichocarpa*) and black poplars (for example, *P. nigra* and *P. deltoides*), aspen cuttings are difficult to root (Hicks 1971). However, Larsen (1943), working with European aspen (*P. tremula* L.), found that aspen could be rooted with ease if cuttings were taken from young, succulent suckers (adventitious shoots) that arise from excised roots. This has become the standard procedure for propagating the species. Various adaptations have been reported by Barry and Sachs (1968), Benson and Schwalbach (1970), Farmer (1963), Hicks (1971), Starr (1971), and Zufa (1971).

Described here are my procedures for vegetatively propagating aspen. They were developed over 8 years while I was studying the species in Utah and adjacent States. These procedures resulted from a synthesis of the literature, personal communications, and my own experiences. There are numerous instances where I have given factual information without citing references. This information is from unpublished personal observations and experimental results on file at the Forestry Sciences Laboratory in Logan.

CLONE SELECTION

Because of its ability to reproduce vegetatively from root suckers, aspen occurs in clones of a few to thousands of genetically identical individuals (Barnes 1966). Although most clones in the central and southern Rocky Mountains range in size from 0.04 to 2.0 ha, clones from 4 to 80 ha are not uncommon (Kemperman and Barnes 1976).

Local populations of aspen show considerable phenotypic variation in morphological and phenological traits (Barnes 1969). After a little experience, one can easily distinguish stems of one clone from stems of a neighboring clone. Characteristics that can be used to identify clones are sex (normally, male and female flowers are on separate trees), leaf morphology, time of bud burst, time of autumn leaf fall, fall leaf coloration, bark color and texture, stem form, and branching and pruning ability. Of course, some traits are seasonal (fall leaf coloration) or can be recognized more easily during one season than others (sex-flowering in spring). There are also clonal differences in some less easily recognized but important characteristics, such as disease resistance (Copany and Barnes 1974; Wall 1971) and growth rate (Garrett and Zahner 1964; Zahner and Crawford 1965).

Clones having desirable characteristics are selected for vegetative propagation. Because the expression of a trait is the result of an interaction of the genotype and the environment where the clone is growing, the trait may change quantitatively, qualitatively, or both when the clone is grown in a new environment. This change can be quite large under conditions of intensive culture (abundant nutrients and water) or if aspen is grown as an ornamental outside of its natural habitat. Traits under a high degree of genetic control will be least affected by environmental change. Although clonal selection and testing have not been performed for aspen, estimates of intraclona variation in natural clones indicate that many of the traits listed above are under a high degree of genetic control (Barnes 1966).

Clones selected for vegetative propagation should be from sites near or similar to the sites where the rooted cuttings will be planted. Until progeny from various source can be tested, planting stock propagated from local aspen is likely to show the best adaptability to the planting site. This criterion is more important for selecting clones for reforestation than for ornamental purposes, because in the latter case such cultural methods as fertilization, irrigation, and pest control can compensate to varying degrees for site deficiences.

ROOT COLLECTION

Suckers can be produced from root cuttings collected at any time of the year. Suckers are fewest in the spring during the flush in shoot growth when high concentrations of endogenous auxins in roots inhibit sucker formation (Schier 1973, 1975). Generally, I have avoided collecting roots during the brief flushing period. Sucker production from roots excised from dormant trees in late summer or fall is often as high or higher than it is in other seasons.

One of the best times to collect roots is in the spring, soon after the snow has melted. Early collections provide sufficient time to grow good-sized plants from rooted sucker cuttings before the onset of dormancy during the shortening days in late summer. Also, moist soils at this time of year make digging easier and lessen the chances of root damage.

When collections are made late in the growing season, rooted cuttings will not grow much before they go dormant. However, artificial lighting can be used to extend day lengths and enable sucker growth to continue into the fall. With late summer or fall collections, it is probably best to store roots and delay propagation of suckers until the following winter or spring.

Equipment helpful in collecting aspen roots are gloves, spade, pruner (anvil type), trowel, and large cloth sacks. A spade is preferable to a shovel because it can be used with more precision and so results in less root damage. The anvil type of pruner works better than the shear type for cutting thick aspen roots. Although sacks of any type of material can be used for root collecting, I have found cloth sacks very useful. They are strong and can be moistened before use to prevent the root sections from drying out.

Lateral roots 1 to 2.5 cm in diameter usually produce the largest number of suckers per unit root length. There is considerable variation in suckering ability among a clone's lateral roots (Schier 1978). For example, the mean number of suckers produced from lateral roots of a single clone ranged from 1 to 23 suckers per 10-cm segment. Therefore, it is wise to collect cuttings from a large number of lateral roots, taking a few roots from each, rather than taking many cuttings from a few lateral roots that may have poor suckering ability.

In aspen clones with regeneration in the understory, roots may be found by digging at the base of suckers. Sometimes, if the soil is moist, roots can be exposed by grabbing a sucker and pulling up the roots. Where regeneration is scarce, it will be necessary to probe for roots with the spade. Roots generally can be found more easily in clones that have a high density of trees. Occasionally, clones are found where shallow lateral roots of a suitable size are difficult to find. In this case, the best chance of finding roots is to dig around the base of mature stems. The difficulty one can have finding aspen roots in the Rocky Mountains would be unusual in the Lake States where shallow roots are generally abundant (Schier and Campbell, 1978).

If roots are not immediately prepared for sucker propagation, they can be stored for brief periods in a cold room or a cool, shaded place after they are wetted down and covered.

ROOT PREPARATION

The most suitable place to prepare roots for sucker propagation is at a sink. Wash off most of the soil from the roots under a stream of tapwater. Then cut off all secondary roots with a single-edged razor blade or a sharp knife. Again, rinse the roots. A soft brush that will not damage the bark is helpful in removing the soil. The lateral roots are then ready for cutting into segments. The length of the segments, generally 10 to 20 cm, should make the most economical use of space in the flats where the suckers are propagated. When cutting the roots, discard portions with such defects as torn bark, scars, cankers, or decay. Root segments may be planted without further treatment or treated to protect them and any emerging suckers from pathogens. I have produced good crops of suckers from "unprotected" cuttings.

Fungi and bacteria can be a considerable problem during the cultivation of root segments. Complete lots of roots can be lost. Major causes are unsanitary conditions, such as accumulations of plant material in the propagating area, unclean tools and plant trays, and contaminated media. The problem is compounded by high temperatures and humidity.

Root cuttings may be protected from pathogens by treating them with fungicides and coating the ends with paraffin. Benson and Schwalbach (1970) recommended dipping root segments in a standard Captain solution (2.5 g/liter). I have treated roots by immersing them for one-half hour in an aqueous slurry of 0.1 percent benomyl (2 g/liter of commercial mixture that contains 50 percent active ingredients), a systemic fungicide.

Paraffin for protecting cuttings should be heated in a container to a temperature just above its melting point. Blot moisture from the end of the root segment with paper toweling and then dip the end in paraffin. Seal exposed tissue by rubbing solidifying paraffin against paper toweling on a hard surface. Repeat the procedure to protect the other end.

Generally, experimental results with growth regulators have been too variable and inconsistent to recommend for stimulating sucker formation. The cytokinins are the most promising group of growth regulators to use in sucker propagation because they are known to induce adventitious buds on roots of many species (Peterson 1975). However, in numerous tests with cytokinins, such as kinetin and benzyladenine, I got little or no increase in sucker production. Apparently, cytokinins that occur naturally in roots were at optimum levels and so outside sources had no effect on suckering.

By soaking excised roots of an aspen clone that showed little natural suckering in kinetin solutions (1 and 5 p/m), Barry (1969) got a significant increase in numbers of suckers appearing on root segments. Thus, it appears that growth regulators can be successfully used in clones having a low suckering capacity (0-2 sucker/10-cm cutting). However, it may be better not to bother with these clones unless they have particularly desirable characteristics.

Root segments should never be treated with auxins (rooting hormones), such as indoleacetic acid (IAA) or indolebutyric acid (IBA), because they inhibit sucker development.

It may be desirable to store aspen roots for varying lengths of time before starting sucker propagation. For example, in the Rocky Mountains, where the snowpack normally makes it difficult to collect roots until May, roots could be collected in October, ahead of snowfall, stored, and planted in February or March. Roots of many clones can be stored for as long as 6 months at 1° to 5°C without any loss in suckering ability. For long-term storage it is probably better to treat root segments with a fungicide, such as Captain or benomyl. To store roots, wrap 5 to 10 segments in moist paper toweling from which excess water has been squeezed and then put them in plastic bags.

SUCKER PROPAGATION

Coarse and fine sands, vermiculite, and mixtures of sand and vermiculite are media that have been used in sucker propagation (Barry and Sachs 1968; Benson and Schwalbach 1970; Maini and Horton 1966; Tew 1970). I have had good success with vermiculite (fig. 1).

Plastic trays with holes for drainage are better than wooden flats for growing suckers because they can be easily washed and sterilized by dipping in 10 percent Clorox. If flats are used, they should be treated with a wood preservative such as Cuprinol.

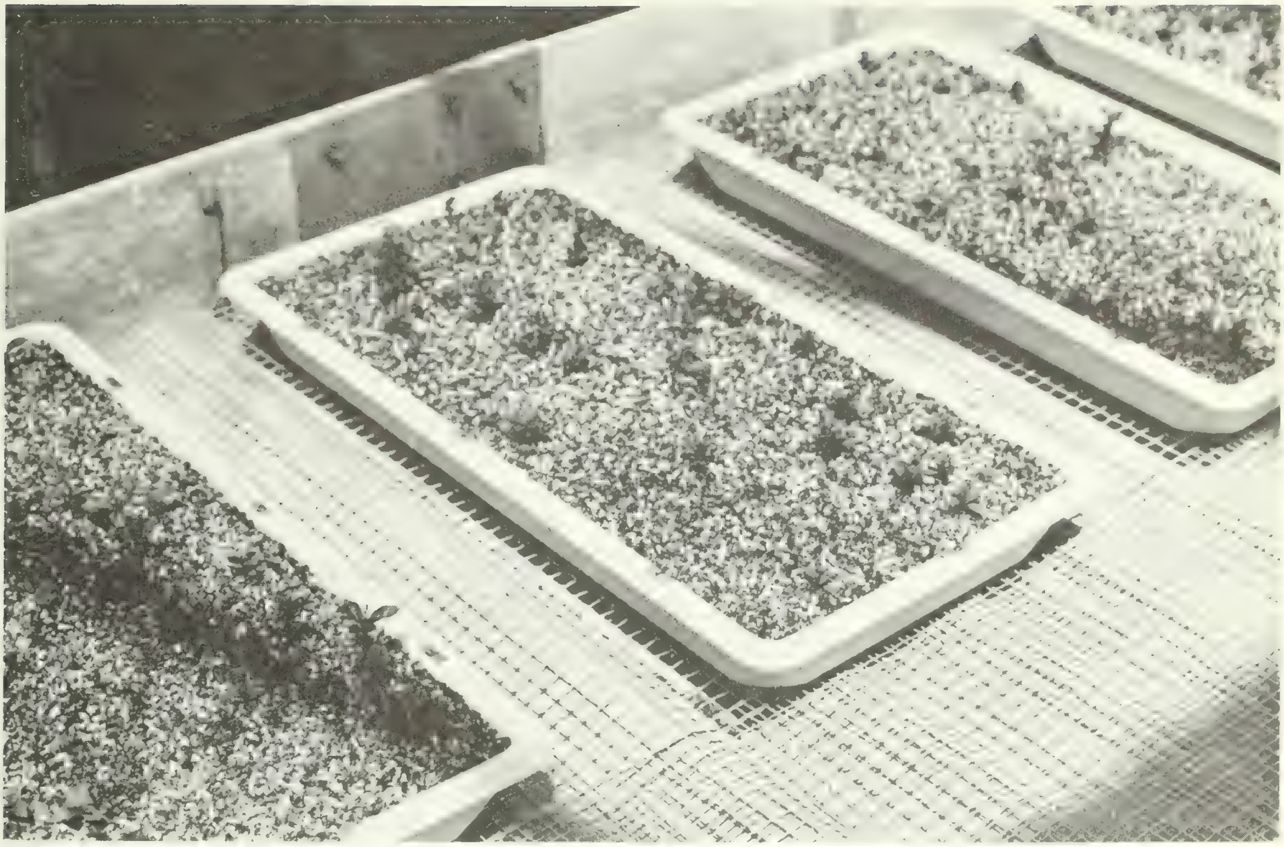

Figure 1.--Suckers growing from aspen root segments planted in vermiculite.

The following procedure is used for planting root cuttings in vermiculite:

1. Label tray with clone designation.
2. Spread dry vermiculite evenly in moistened tray (prevents vermiculite from falling through holes) and pack it down with a block of wood so that the level is 3 cm from top of the tray.
3. Lay out root segments approximately 1 cm apart on vermiculite. Press large diameter segments into vermiculite.
4. Cover segments with vermiculite. Bring vermiculite to the top of the tray after spreading and packing. The segments will be at a depth of 1 to 2 cm.
5. Wet down vermiculite thoroughly using a spray nozzle.

Suckers will grow over a considerable temperature range (Zasada and Schier 1973). For best growth, daytime temperatures probably should be between 20° and 30°C. Nighttime temperatures can be lower, but should not fall below 10°C.

Planted root cuttings should be given only enough water to keep them from drying. There is a tendency for most people to overwater, which increases the risk of disease.

The maximum number of suckers are produced in about 5 to 6 weeks (fig. 2). Height growth also levels off by this time. Delay in harvesting can result in losses caused by root decay. Decay can occur after suckers emerge and can be so serious on roots of some clones that large numbers of suckers are lost. The susceptibility of roots to decay varies considerably among clones. I have found the proportion of segments with decay to range from 0 to 75 percent.

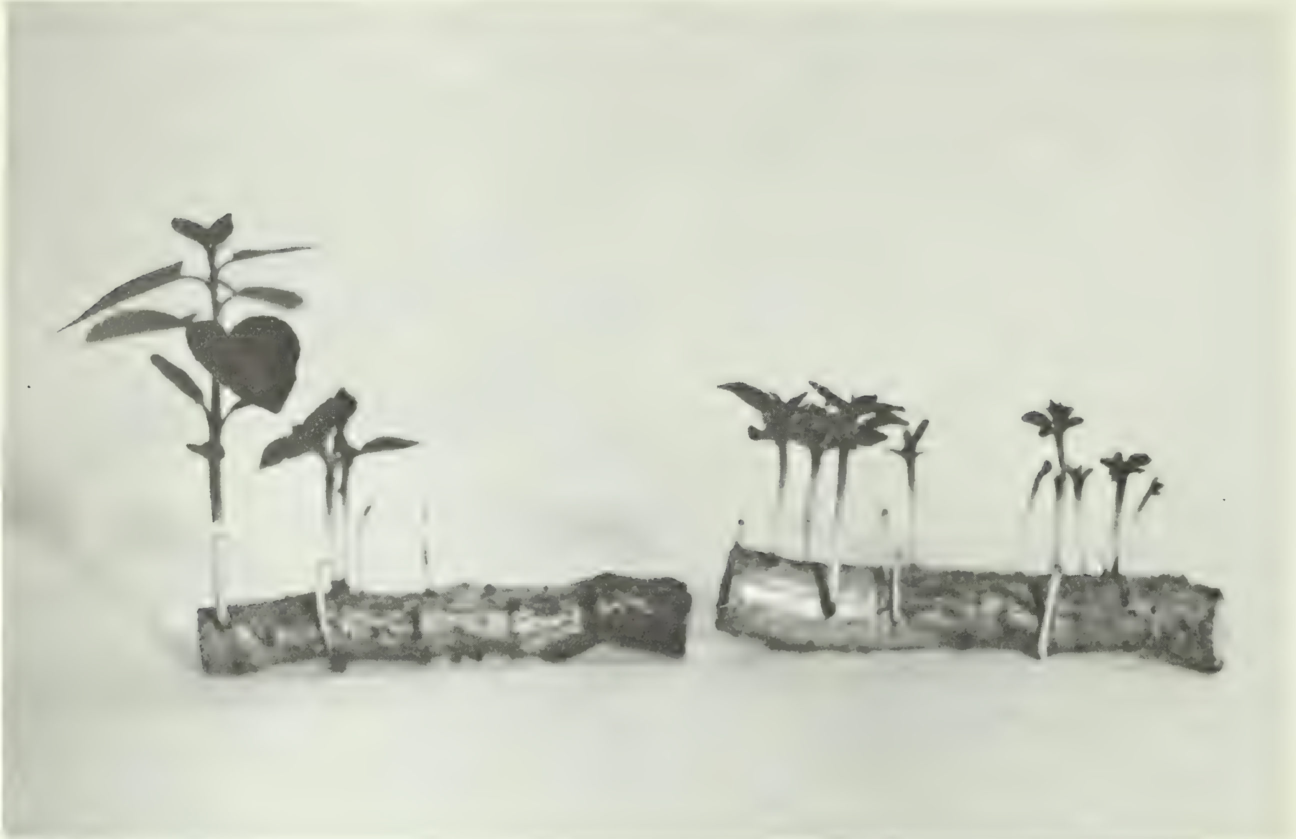

Figure 2.--Aspen suckers on 8-cm root segments from two different clones.

Clonal variation in sucker production from aspen root cuttings has been widely reported (Farmer 1962; Maini 1967; Schier 1974; Steneker 1972; Tew 1970; Zufa 1971). Comparing roots from 20 clones collected in September on the Cache National Forest in northern Utah, I found that sucker production ranged from 4 to 21 suckers per 10-cm cutting. A clone may also show a considerable seasonal variation in sucker production (Schier 1973). The greatest change I found in sucker production from one date to another for a clone was from 2.7 suckers/10-cm cutting in August to 18.5 suckers/10-cm cutting in October.

Once desirable clones are under propagation, sucker cuttings may be obtained from suckers induced by decapitating potted aspen plants. Suckers arising from the roots of these plants are larger and more vigorous than suckers from excised roots.

ROOTING SUCKER CUTTINGS

Cut suckers 2 cm and larger in height from root segments with a sterilized razor blade or Exacto cutting knife and place them in a tray of water. Do not remove more suckers than can be planted in the rooting media during the same day. Mottled areas appear on leaves of sucker cuttings held in water for more than 1 day. These later become necrotic and increase losses during rooting.

Coarse sand (Farmer 1963), shredded sphagnum moss (personal communication, Burton V. Barnes, University of Michigan), mixtures of sand and vermiculite (Benson and Schwalbach 1970), or perlite and vermiculite (Barry and Sachs 1968) are media that have been used for rooting sucker cuttings. I have had good success with a 1:1 perlite-vermiculite mixture; it has sufficient porosity to allow good aeration, a high water-holding capacity and, yet, it is well drained. The rooting medium is placed in well-drained sterilized trays, treated wooden flats, or small containers for single cuttings. I use 19.5- by 27.5-cm plastic trays that will hold 120 cuttings (2.3- by 1.8-cm spacing).

If space is not limited in the rooting area or if only a small number of rooted cuttings are desired, single cuttings can be rooted in small containers. The advantage of this method is that cuttings need not be transplanted once they develop roots. Thus, the roots are not disturbed and a propagation step is eliminated. However, it is difficult to find a medium that is good for both rooting and growth of the cutting. B. V. Barnes (personal communication) reports that he has successfully propagated single aspen in Jiffy-7 peat pots (peat enclosed in a plastic net, 4.4 cm in diameter by 5.4 cm in height). Because of its high water-holding capacity, there is a danger that the peat will become too wet under a mist and cause the newly formed roots to deteriorate.

It is good practice to treat sucker cuttings from all clones with indolebutyric acid (IBA), a root-promoting growth regulator (hormone) This auxin increases the percentage of cuttings rooting for clones with low-rooting capacities and increases the number of roots on cuttings of all clones (Farmer 1963). IBA increases root number by causing roots to be initiated on a larger area of the sucker stem.

Cuttings can be treated by dipping the basal ends into talcum powders containing IBA or by quickly dipping the ends into solutions of IBA. Commercial powder preparations of IBA, such as Hormodin,[1] at various concentrations are available. Although powders containing 0.1 percent IBA are usually recommended for succulent cuttings, I have had better success with concentrations of 0.3 to 0.8 percent. Concentrations as high as 1.6 percent do not inhibit sucker initiation but may cause a reduction in root growth. IBA powders should be stored at 0° to 5°C in tightly sealed containers. Allow the container to come to room temperature before opening it to avoid condensation of moisture.

The cuttings should not be dipped into the entire stock of IBA powder because foreign material and moisture may contaminate the hormone and cause it to deteriorate. Instead, place a small sample of hormone powder on wax paper, in a bottle cap or a jar cover. After treating the cuttings, discard any powder that remains. Procedures for treating sucker cuttings with rooting powders and planting them in the rooting media are as follows:

1. Remove excessive water from the base of a cutting by blotting it with paper toweling.
2. Dip and rotate base of cutting in powder until a length of 1 to 2 cm (greater length on taller cuttings) is covered. Tap the cutting lightly to remove excess powder.
3. Make a small hole in rooting medium with a narrow spatula, ice pick, spoon handle, or similar tool. Insert cutting to a depth of 1 to 3 cm so that one-half to one-third of the stem is in the medium. Be careful not to brush off the powder. Press in side of hole so the medium holds the cutting firmly.
4. Plant cuttings at an approximate 2- by 2-cm spacing.

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[1] Rootone, containing napthaleneacetic acid (NAA), IBA, and other auxins, may also be suitable.

Quick-dip solutions for treating sucker cuttings are prepared by dissolving IBA crystals (available from chemical supply houses) in 50 percent alcohol (ethanol or isopropanol). They generally give more uniform results than IBA powders. Testing the effects of solutions containing 0, 1,000, 2,000, 4,000, 8,000, and 16,000 p/m IBA on rooting, I found that the percentage of suckers rooting and number of roots initiated increased with IBA concentration. IBA did not stimulate root elongation. At 16,000 p/m there was a slight inhibition. Barry and Sachs (1968) found that concentrations of IBA higher than 1,000 p/m caused deterioration of sucker cuttings from California clones and less vigorous root growth. The differences in our results may be due to differences in methods or to clonal variation in response to IBA.

A small volume of 4,000 p/m (0.4 percent) quick-dip solution can be prepared by dissolving 400 mg of IBA in 100 ml of 50 percent alcohol. Only a small portion of this should be used in treating cuttings. Remove excess water from cutting and dip basal 1 to 2 cm in solution for about 5 seconds. Plant as described above. The IBA solution should be tightly sealed and stored at 0° to 5°C when not in use.

As in the propagation of suckers, control of pathogens is important for successful rooting. The best way to achieve this is to maintain sanitary conditions in the rooting area and to use sterilized tools and equipment. Although generally I have found it unnecessary, cuttings can be treated with systemic fungicides, such as benomyl. Some commercial rooting powders contain fungicides (for example, Rootone F).

A misting bench is the most suitable place to root sucker cuttings. In our greenhouses, we use a misting schedule that varies from 1 minute of mist every 5 minutes during the warmest part of the day to 1 minute every 20 minutes during the night. Temperatures should probably be kept between 20° and 25°C, although night temperatures can be slightly lower.

For those who do not have misting facilities, sucker cuttings can be rooted under polyethylene sheeting. Rooting chambers can be built by constructing a wooden frame and covering it with sheeting. The simplest chamber can be made by sealing a rooting tray in a polyethylene bag (Benson and Schwalbach 1970). High humidity within the rooting chamber will keep the succulent cuttings turgid. The chambers should be kept out of direct sunlight so that temperatures within do not become too high. A major disadvantage of rooting chambers is the lack of ventilation, which can cause problems with pathogens.

Sucker cuttings from most clones produce well-developed root systems in 2 to 3 weeks (fig. 3). Keeping cuttings under mist for longer periods increases the danger that necrotic areas will form and leaves will abscise. As might be expected, there is considerable clonal variation in root development. This is caused by an interaction of natural rooting ability (Schier 1974) and sensitivity to the rooting hormone.

To remove sucker cuttings from the rooting medium so that loss of fragile roots is kept to a minimum, the medium should be saturated with water and the cuttings carefully lifted with a small spatula. With trays, this can be easily accomplished by nesting the rooting tray in an empty tray without holes and adding water until the rooting tray overflows. The rooted cuttings should be held in water until they can be planted.

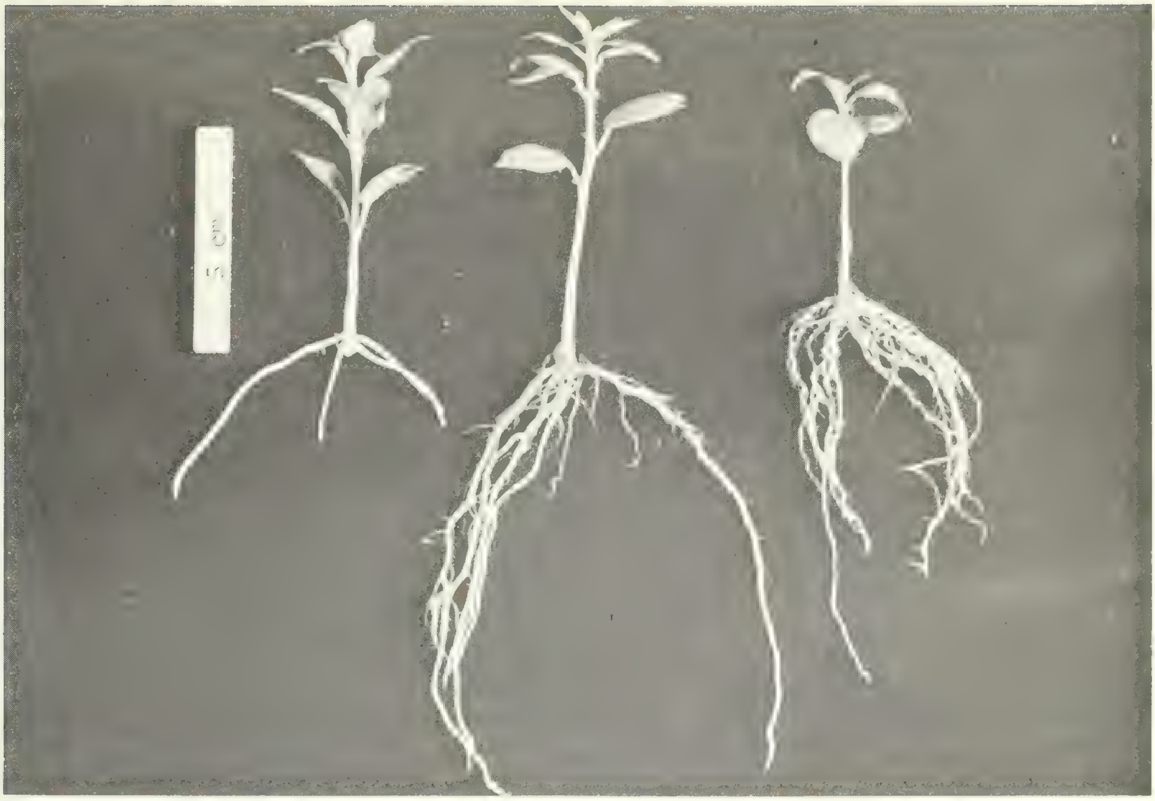

Figure 3.--Rooted sucker cuttings from a single aspen clone showing various types of adventitious root development. Cuttings were treated with 0.2 percent indolebutyric acid in powder and rooted under mist for 3 weeks.

CULTIVATING ROOTED CUTTINGS

Rooted cuttings can be planted in pots or in the types of containers widely used in producing container-grown coniferous seedlings for reforestation. I have grown aspen cuttings in a number of large containers and have been satisfied with the results (fig. 4). One of their major advantages is that a number of plants with deep root systems can be grown in a small area. The size of the largest tube is 5.2 cm in diameter by 25 cm in length. After one growing season, the containers are filled with roots and the cuttings can be outplanted or transferred to large pots.

A good potting medium is a 1:1 vermiculite-peatmoss mixture. The mixture should be moistened to the point where a few drops are released when it is squeezed. When the rooted cuttings are planted, care should be taken to make sure that the roots are well spread. A good practice in planting most cuttings is to form the medium into a dome near the top of the container, spread the roots around it, and then add more medium.

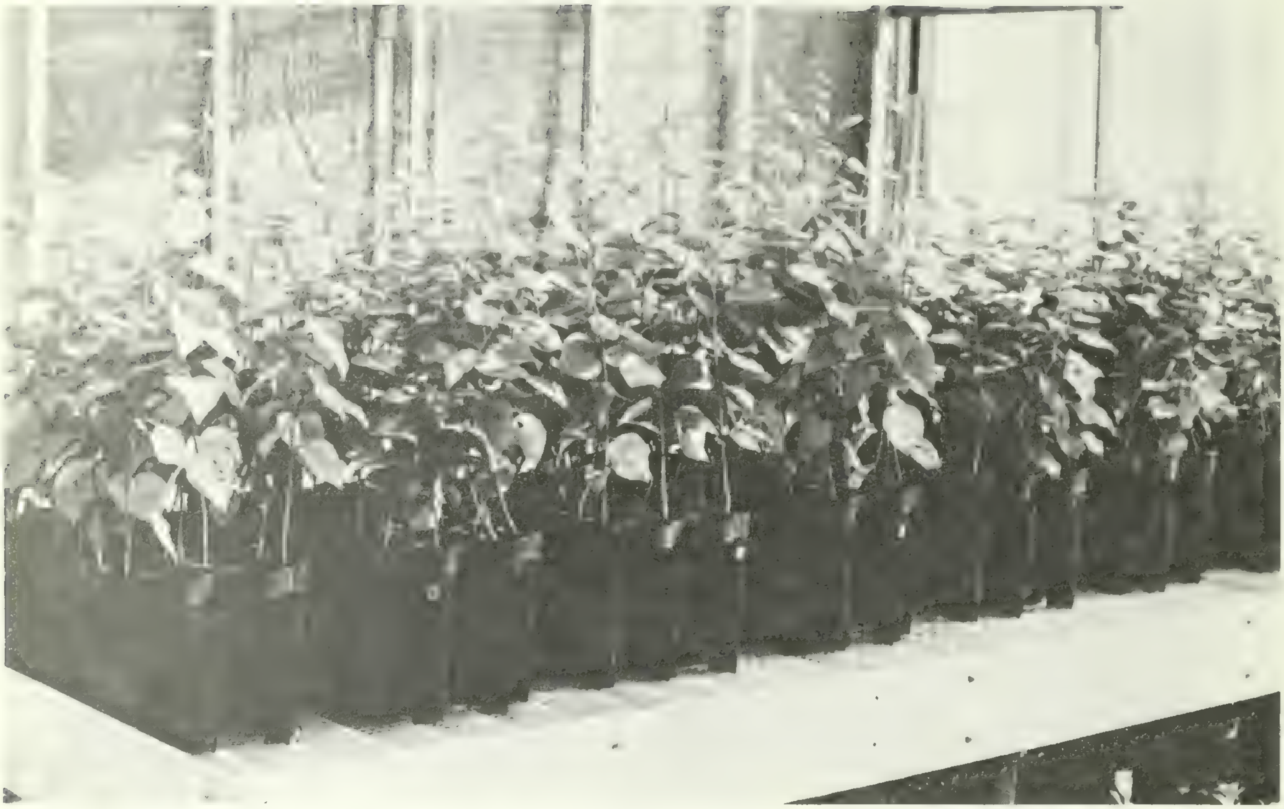

Figure 4.--Aspen growing in tubes (top diameter, 5.2 cm; length, 25 cm)--November 5, 1976. Rooted cuttings were planted July 19 to 23. They were given supplemental lighting from August 1 to November 1.

Shortly after the cuttings are planted, they should be fertilized with a complete commercial fertilizer. We have produced vigorous, healthy plants with Scotts 20-4-8 Shrub and Tree Fertilizer that contains all the essential micronutrients. One-fourth teaspoon of this fertilizer is applied to the tubes (described above and shown in figure 4) at planting time, after 1 month, and in the fall.

While the sucker cuttings are becoming established and still soft and succulent, direct sunlight should be avoided. Watering should be done with care. Too much water can be as harmful as too little because it can result in mortality caused by damping-off fungi.

To obtain maximum growth of the cuttings ahead of dormancy, it is often necessary to extend day lengths with artificial lighting. We generally put on the lights to extend the day length to 16 hours during the first week in August and take them off in early November. B. V. Barnes (personal communication) has successfully extended the growing season of aspen with continuous light. Intermittent light, such as 1 minute of incandescent light every 15 minutes through the night, may be more effective for maintaining growth (personal communication, R. W. Tinus, Rocky Mountain Forest and Range Experiment Station).

In November, the cuttings are moved to a section of the greenhouse where the temperatures range from 2° to 10°C. These temperatures satisfy the cold requirements of Utah aspen as indicated by a normal spring bud break. In plants whose cold requirements have not been satisfied, the terminals and upper laterals remain dormant while the lower laterals flush out. If plants are moved outdoors for overwintering, they should be moved in late September so that they will have adequate time to harden-off. So that plants do not flush out before outplanting, it may be necessary to move them to a cold room in early spring. This is a common practice when trees grown at low elevations are to be outplanted on high elevation sites where lingering snow cover prevents early planting.

Some mortality can be expected after rooted cuttings are planted in containers. Also, some cuttings make little shoot or root growth even when given supplemental lighting. Buds form during rooting and a cold treatment is necessary before shoot growth will continue. Early bud set occurs with greater frequency in some clones than in others. Cuttings that do not grow much the first growing season must be held in the containers for another year before they can be outplanted. For certain purposes, this might be considered an undesirable characteristic; so such clones are eliminated from future propagation plans.

Pest problems we have encountered with aspen grown in containers are aphids, red spider mites, and powdery mildew. Aphids can be controlled with Isotex. Kelthane is very effective against mites. Insect pests in greenhouses can also be controlled by fumigating with various chemicals. Powdery mildew can be stopped from spreading if all plants are immediately sprayed with benomyl when the mildew is first detected. Once it becomes established, I know of no way to get rid of it before autumn leaf fall.

OUTLINE — VEGETATIVE PROPAGATION PROCEDURES

1. Select clones with desirable phenotypic characteristics.

2. Excavate roots. Be sure to take cuttings from a large number of lateral roots.

3. Wash soil from roots, remove all secondary roots, and cut into lengths suitable for planting.

4. Treat root segments with a fungicide and then seal ends with paraffin.

5. Plant segments to a depth of 1 to 2 cm in vermiculite in trays. Moisten vermiculite.

6. Place trays in a greenhouse where the diurnal air temperature ranges between 25° and 15°C and water lightly each day.

7. After 6 weeks, remove suckers 2 cm and larger from root segments.

8. Treat basal ends of sucker cuttings with indolebutyric acid (IBA) in powder or 50 percent alcohol.

9. Insert sucker cuttings in moist vermiculite:perlite (1:1) so that one-half to one-third of the stem is in the medium.

10. Place sucker cuttings on a misting bench or in a high-humidity, polyethylene chamber.

11. After 2 to 3 weeks, remove rooted cuttings from rooting medium.

12. Plant rooted cuttings in containers with a peat moss:vermiculite (1:1) mixture and fertilize with a complete fertilizer.

13. Grow aspen in an environment where the approximate temperature range is 15° to 25°C. Provide supplemental lighting so growth will be prolonged during short days.

14. During the winter, satisfy the chilling requirements of the cuttings by placing them outdoors or at a temperature of 2° to 10°C.

15. In the spring, outplant dormant cuttings or transfer them to large pots.

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Schier, George A.
1978. Vegetative propagation of Rocky Mountain aspen. USDA For. Serv. Gen. Tech. Rep. INT-44, 13 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

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KEYWORDS: *Populus tremuloides*, sucker propagation, rooting cuttings, containerized aspen planting stock

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GRAPHIC AIDS FOR FIELD CALCULATION OF DEAD, DOWN FOREST FUELS

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CONTENTS

Page

PLANAR INTERSECT SAMPLING 1

HOW THE GRAPHS ARE USED 4

HOW FUEL LOADING DETERMINATIONS CAN BE IMPROVED . 7

Slope 7
Specific Gravity 8
Mean Diameter Per Size Class 9

SUMMARY 9

PUBLICATIONS CITED 10

APPENDIX A 11

How the Graphs Were Developed 11

APPENDIX B 13

Tearouts for Computing Fuel Load, Corrections for Slope and Specific Gravity 15

RESEARCH SUMMARY

Increased field activities in fuel inventory have emphasized the need for methods to rapidly interpret data collected with the planar intersect sampling technique. Fuel load calculations by size class are being used as input to fire and fuel management, residue utilization, and land management planning. Rapid conversion of the data to numbers usable in the field can be accomplished with these graphic aids that complement but do not replace automatic data processing capabilities.

The graphic aids allow fuel load calculations by size class for quick field assessment. They allow adjustments for variations in slope and specific gravity of the woody material. Any greater degree of resolution should be accomplished through data processing facilities.

PLANAR INTERSECT SAMPLING

In *Handbook for Inventorying Downed Woody Material* Brown (1974) tells how to determine the quantity of fallen fuel by means of planar intersect sampling. These procedures have been used in fire management planning, timber stand inventories, and in residue utilization studies. When large areas are sampled, large amounts of data result, which makes computer processing desirable for computing fuel loads. Computer processing of data is available through the Fort Collins Computer Center Univac 1100/40 or the Lawrence-Berkeley Laboratory's CDC 7600 using the program DFINV.

Managers lack easy-to-use computational aids for quickly determining fuel loads in the field; therefore, it is difficult to compare the appearance of a stand when sampled with the determined fuel load. Also, for small amounts of data it is faster to calculate loadings by hand. In 1975, as fuel inventory activities increased in the West, graphic aids were developed in response to field requests for assistance. This paper provides graphic aids to facilitate calculating fuel loads from planar intersect sampling.

Information for calculating loading in Brown's (1974) *Handbook for Inventorying Downed Woody Material* has been consolidated into two graphs. These graphs use fuel inventory data to determine the fuel load in tons per acre for each size class of fuel: <0.25 inch (0.6 cm); 0.25 to 1.0 inch (2.5 cm); 1.0 to 3.0 inches (7.6 cm); and 3+ inches sound and dead. As a result of favorable field response to use of the graphs, forms were prepared for use in the Intermountain Region (Region 4).

This paper presents the graphs used in the Intermountain Region, (fig. 1 and 2) with the addition of corrections for slope and fuel density (specific gravity). Assumptions, use of the graphs, specific site corrections, and mean diameter effects are discussed to aid the user in improving determinations of fuel load.

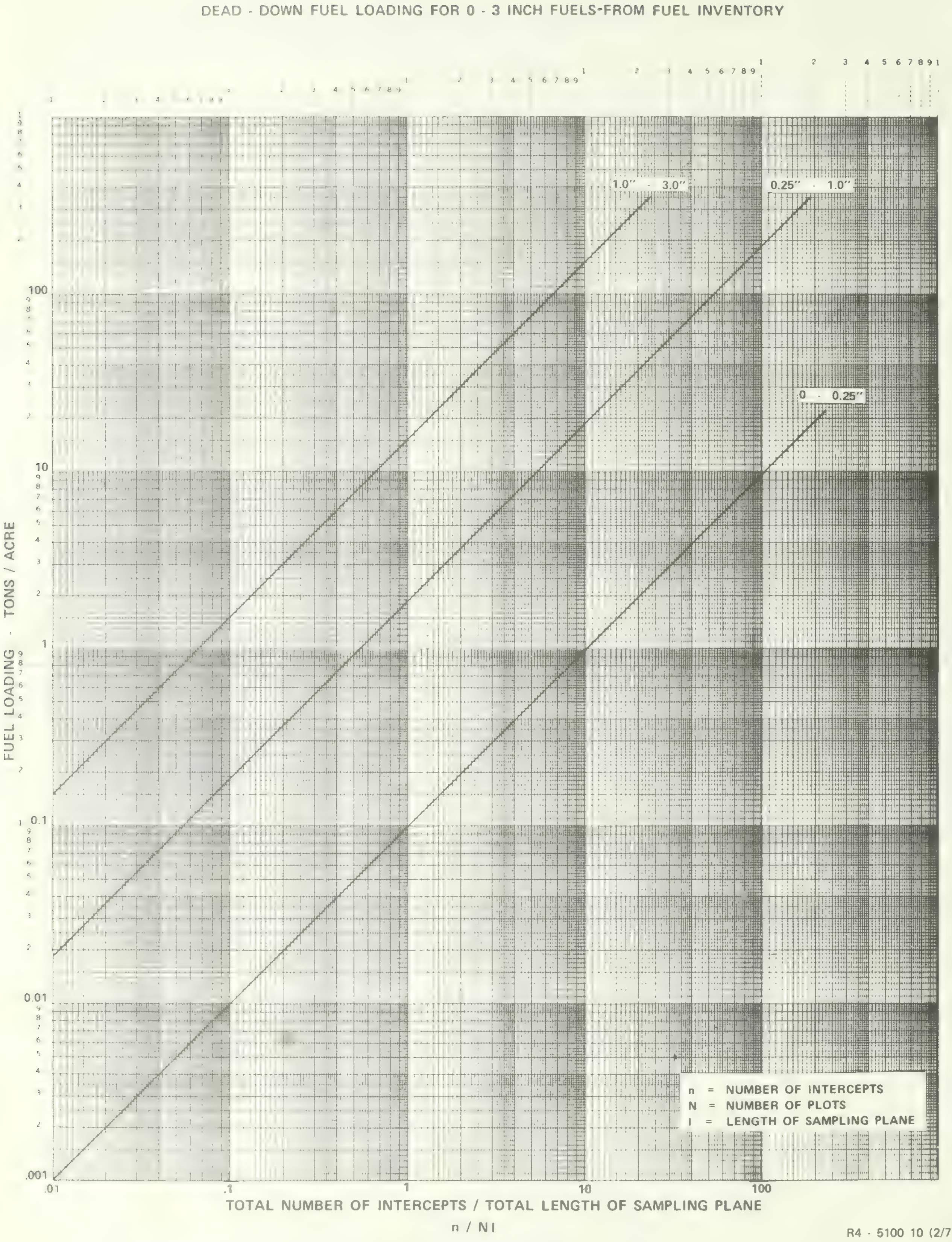


Figure 1.--Dead-down fuel load by size class from number of intercepts and transect length.

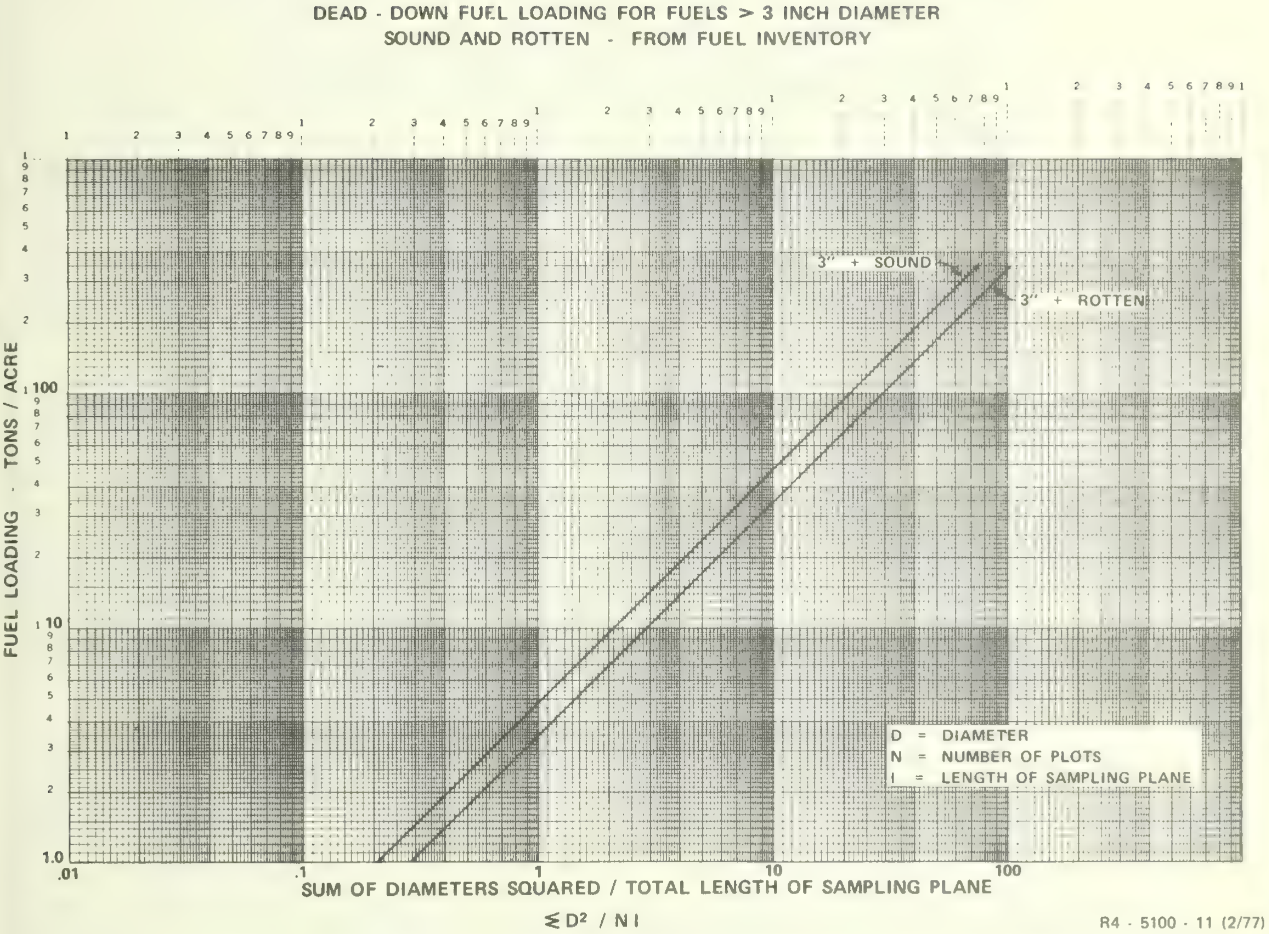


Figure 2.--Dead-down fuel load for greater than 3-inch-diameter sound and rotten wood, from diameters and transect length.

HOW THE GRAPHS ARE USED

To demonstrate the use of the graphs in figures 1 and 2, the field tally of data presented by Brown (1974) is used (fig. 3). With the data form (fig. 3) and preferably a pocket calculator available in the field, one can determine the fuel load with the graphs as follows:

1. *Size class less than 0.25 inch (0.6 cm).*--From the data sheet (fig. 3), we can see that the number of plots, N, is 2; the number of intersects (n) is 24 + 8 = 32; and the transect or sampling plane length (ℓ) is 6 ft (1.8 m). The result of $n/N\ell$, $32/(2\times6)$ is 2.67. The fuel load is found from figure 1 by entering 2.67 on the X-axis, going vertically to the line for the <0.25-inch size class, turning 90° to the left to the Y-axis where a value of about 0.28 ton per acre (0.63 ton (metric) per hectare) is read. Enter and read the values carefully because of the logarithmic scales.

2. *Size class 0.25 to 1.0 inch (2.5 cm).*--$N = 2$, $n = 9 + 2 = 11$, and $\ell = 6$ ft (1.8 m). The result, $n/N\ell$, is $11/(2\times6)$ or 0.92. Proceeding as before but using the line for the 0.25- to 1.0-inch size class, the fuel load is about 1.68 tons per acre (3.8 t/ha) without any slope correction.

3. *Size class 1.0 to 3.0 inches (7.6 cm).*--$N = 2$, $n = 3$, $\ell = 10$ ft (3.1 m). The result is $3/(2\times10)$ or 0.15 and the load is found to be near 2.18 tons per acre (4.9 t/ha

4. *Size class sound 3+ inches.*--Above 3-inch diameter, the intercepts are tallied by the diameter of each piece and the squared diameters (d^2) are summed (Σ) as follows:

$$\Sigma d^2 = (10)^2 + (3)^2 + (8)^2 + (12)^2 = 100 + 9 + 64 + 144 = 317.$$

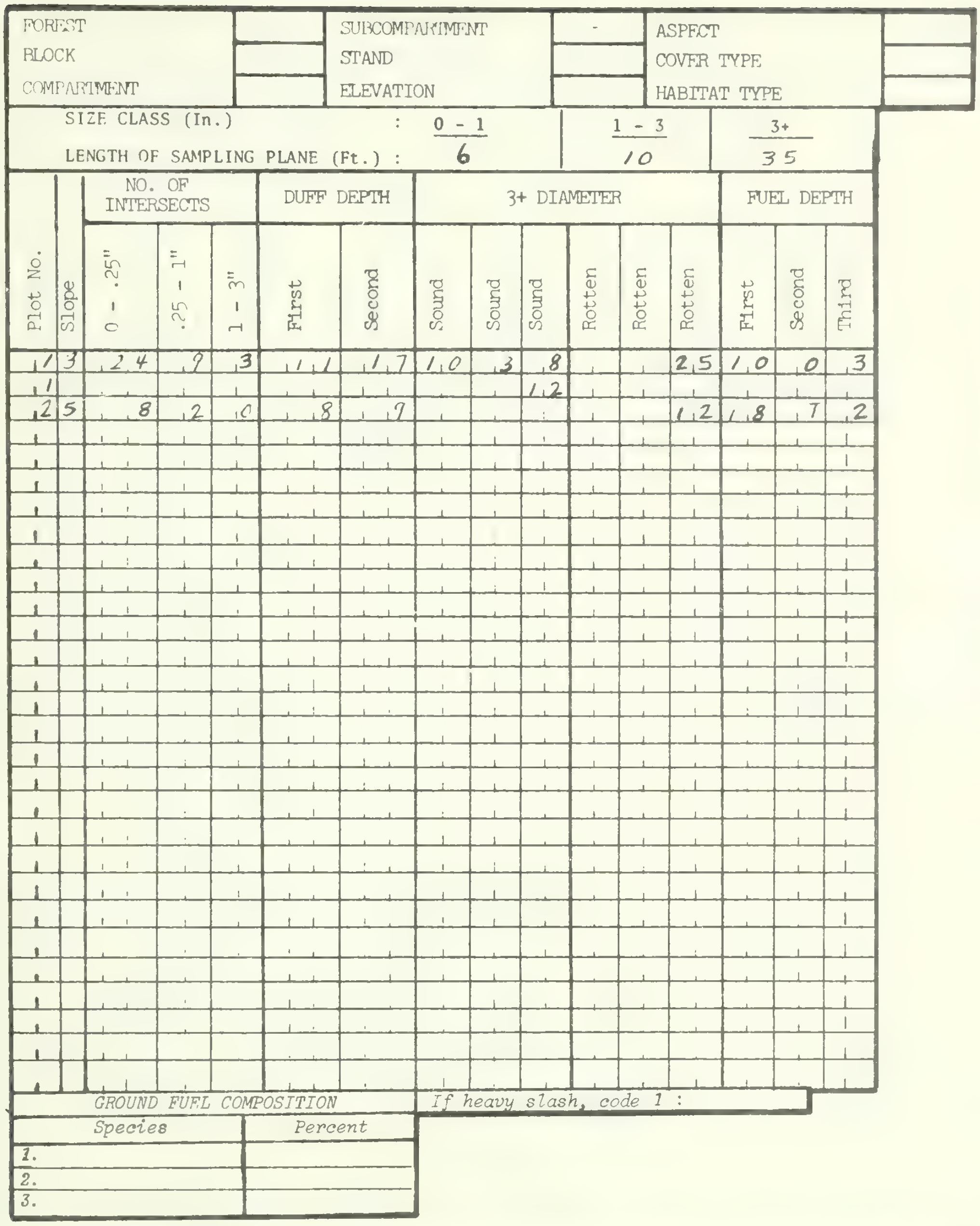
The result, $\Sigma d^2/N\ell$, is $317/(2\times35)$ or 4.53 and the fuel load is found on figure 2 to be near 21.1 tons per acre (47.3 t/ha).

5. *Size class rotten 3+ inches.*--The result, $\Sigma d^2/N\ell$, is $769/(2\times35)$ or 10.99 and the fuel load is near 38.3 tons per acre (85.9 t/ha).

The estimated total fuel load is the sum of all size classes:

0.28 + 1.68 + 2.18 + 21.1 + 38.3 = 63.5 tons per acre (142 t/ha).

DOWNED FUEL INVENTORY



FOREST		SUBCOMPARTMENT	-	ASPECT	
BLOCK		STAND		COVER TYPE	
COMPARTMENT		ELEVATION		HABITAT TYPE	

SIZE CLASS (In.) :	0 - 1	1 - 3	3+
LENGTH OF SAMPLING PLANE (Ft.) :	6	10	35

		NO. OF INTERSECTS			DUFF DEPTH		3+ DIAMETER						FUEL DEPTH		
Plot No.	Slope	0 - .25"	.25 - 1"	1 - 3"	First	Second	Sound	Sound	Sound	Rotten	Rotten	Rotten	First	Second	Third
1	3	24	9	3	11	17	10	3	8			25	10	0	3
1									12						
2	5	8	2	0	8	9						12	18	7	2

GROUND FUEL COMPOSITION	*If heavy slash, code 1 :*

Species	*Percent*
1.	
2.	
3.	

Figure 3.--Sample of a field tally sheet with typical computations (after Brown 1974).

When using the graphs to estimate fuel load in size classes under 3 inches you must consider the *number of interceptions* for that size class. Categories above 3 inches must consider the *sum of the squared diameters* for the pieces intercepted. Do not try to estimate the greater than 3-inch fuel loads using figure 1 or less than 3-inch fuel loads from figure 2. Serious errors in the estimates will result. Another common source of error is to carry the same sampling plane length over from one size class to another. Always note the transect distance used. Another source of error is incorrect entry on the logarithmic scale; always note the correct value.

Table 1.--*Sum of squared diameters for a given diameter and interceptions up to 10*

Diameter	Diameter²	Σd² for (n) - number of pieces intercepted										
		1	2	3	4	5	6	7	8	9	10	
Inches	*In²*											
3	9	9	18	27	36	45	54	63	72	81	90	
4	16	16	32	48	64	80	96	112	128	144	160	10 tons/acre
5	25	25	50	75	100	125	150	175	200	225	250	
6	36	36	72	108	144	180	216	252	288	324	360	
7	49	49	98	147	196	245	294	343	392	441	490	
8	64	64	128	192	256	320	384	448	512	576	640	50 tons/acre
9	81	81	162	243	324	405	486	567	648	729	810	
10	100	100	200	300	400	500	600	700	800	900	1,000	
11	121	121	242	363	484	605	726	847	968	1,089	1,210	
12	144	144	288	432	576	720	864	1,008	1,152	1,296	1,440	
13	169	169	338	507	676	845	1,014	1,183	1,352	1,521	1,690	150 tons/acre
14	196	196	392	588	784	980	1,176	1,372	1,568	1,764	1,960	
15	225	225	450	675	900	1,125	1,350	1,575	1,800	2,025	2,250	
16	256	256	512	768	1,024	1,280	1,536	1,792	2,048	2,304	2,560	
17	289	289	578	867	1,156	1,445	1,734	2,023	2,312	2,601	2,890	
18	324	324	648	972	1,296	1,620	1,944	2,268	2,592	2,916	3,240	
19	361	361	722	1,083	1,444	1,805	2,166	2,527	2,888	3,249		300 tons/acre
20	400	400	800	1,200	1,600	2,000	2,400	2,800	3,200			
22	484	484	968	1,452	1,936	2,420	2,904	3,388				
24	576	576	1,152	1,728	2,304	2,880	3,456					
26	676	676	1,352	2,028	2,704	3,380						
28	784	784	1,568	2,352	3,136							
30	900	900	1,800	2,700								
35	1,225	1,225	2,450									
40	1,600	1,600	3,200									
45	2,025	2,025										
50	2,500	2,500										
60	3,600	3,600										
70	4,900	4,900										
80	6,400	6,400										
90	8,100	8,100										

It is recommended that a field form similar to figure 3 be used to collect data for each stand inventoried. To effectively use the graphs, you must have the number of intercepts (n) in each size class; the sum of the diameters squared (Σd^2) of pieces larger than 3-inch diameter; the number of plots (N) taken in the stand; and the length (ℓ) of the sampling plane used for each size class.

In many inventories, several intercepts can be made of material of the same diameter. To simplify the arithmetic, table 1 was generated to present the Σd^2 for diameters from 3 to 90 inches (7.6 to 229 cm) and interceptions from 1 to 10 pieces. The user simply has to add together the values for each diameter intercepted. For example, assume the following sound 3+ inch field data:

Diameter	*Interceptions*	*Σd^2 (from table 1)*
3	6	54
7	2	98
10	4	400
	Total	552

With the previous number of plots (N) of 2 and a transect length (ℓ) of 35 feet (10.7 m), the result of $\Sigma d^2/N\ell$ is 552/(2×35) or 7.88. The fuel load of sound 3+ inches would be 37.5 tons per acre (84.1 t/ha), from figure 2. Table 1 can be used to determine the sum of d^2 for either sound or rotten material. The lines for 10, 50, 150, and 300 tons per acre (22.4, 112, 336, and 673 t/ha) were determined for a single plot in a 50-ft (15.2-m) transect length. These lines mark off what is generally considered light, medium, and heavy loadings and may help the user to more quickly identify fuel loadings in the field.

HOW FUEL LOADING DETERMINATIONS CAN BE IMPROVED

Accuracy of graphic aids can be improved by refining the data in the calculations. The intent of the graphic aids, however, is to provide an easy and rapid way to determine fuel loads in the field. The data could be readily improved by correcting for slope and the specific gravity of the size classes. Improvements are also possible by adjusting the mean diameter of the size classes or allowing for differences in the nonhorizontal correction factor. However, these latter improvements would be best handled in the computer for analysis that requires the detail.

Slope

When fuels are sampled on a slope and the data are to be considered on a horizontal projection, a slope correction factor should be applied. It is desirable that the slope along the transect plane be noted and used for the correction. If slope was not recorded but the general slope of the site is available, a value equal to one-half the general slope should be used. This is because the sampling plane has equal opportunity to be on any slope between zero and the general slope. Once a slope has been selected, the correction factor, c, can be determined from figure 4 up to 110 percent slope. The slope correction factor is multiplied times the total fuel load, or specific size class fuel loads, as desired. If a total estimate of the fuel load is desired, the simplest approach is the single calculation using total fuel load.

On rare occasions, the transects may be located on slopes greater than 110 percent. To determine the correction factor in those cases, the equation for the correction factor can be used:

$$c = \sqrt{1 + \left[\frac{\text{Percent slope}}{100}\right]^2}. \tag{1}$$

For the data presented in figure 4, the total fuel load was 63.5 tons per acre (142 t/ha) with no slope correction. If the assigned slope were 80 percent, the total fuel load would be multiplied by the correction factor of 1.28 (from fig. 4), 63.5 × 1.28 = 81.3 tons per acre (182 t/ha) on the flat. For slopes less than 30 percent, load determinations are low by less than 5 percent, if no correction is made.

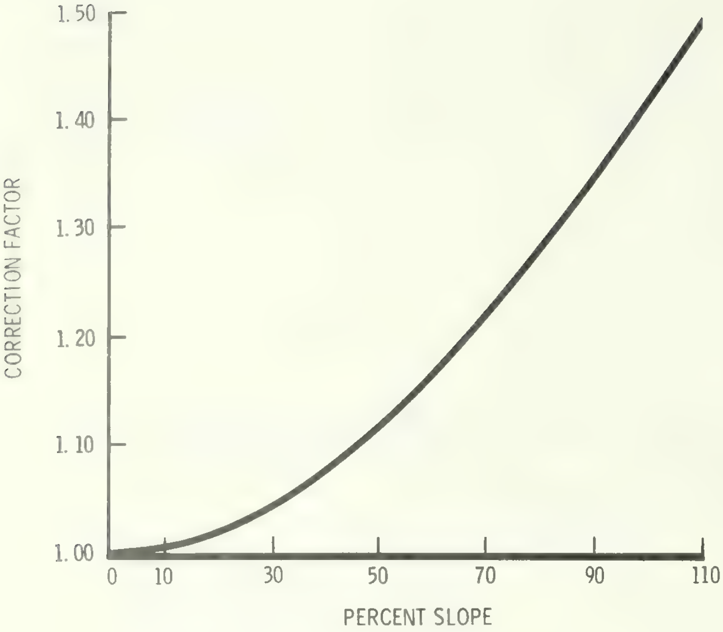


Figure 4.--Correction factor to be multiplied by fuel load to account for slope.

Specific Gravity

Estimates of fuel loads can also be improved by assigning specific gravities to each size class. If one knows the specific gravity of the timber type in which the inventory is being made, correction for specific gravity can be made using figure 5. For the less than 1.0-in (2.5-cm) diameter classes, a reference specific gravity of 0.48 is used (fig. 5). For the size classes greater than 1.0, the reference specific gravity is 0.40. This is presented by the upper line in figure 5.

Correction for each size class can be made from figure 5. The fuel load determine from figures 1 and 2 is multiplied by the correction factor. For example, if the specific gravity for all sound wood size classes is 0.6 for the example on page 4, item 5, the correction factor for less than 3-inch material is 1.25 and 1.50 for the 3-inch plu material:

1. <0.25-inch size class: w = 0.28 × 1.25 = 0.35
2. 0.25- to 1.0-inch size class: w = 1.68 × 1.25 = 2.10
3. 1.0- to 3-inch size class: w = 2.18 × 1.50 = 3.27
4. 3+-inch sound size class: w = 21.1 × 1.50 = 31.65
5. 3+-inch rotten size class: w = 38.3 × 1.00 = 38.3

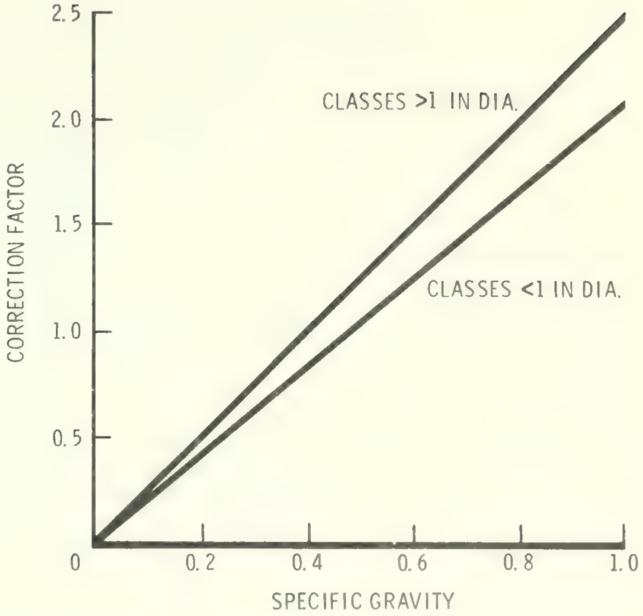
75.9 tons/acre (170 t/ha).

The previous no-slope total load was 63.5 (142 t/ha), so the change in specific gravity increased the original load determination by 19 percent.

Wood Handbook No. 72 rev. (U.S. Forest Products Laboratory 1974) gives the specifi gravity for the various woods of the United States at 12 percent moisture content. For softwoods, the range in specific gravity is from 0.31 to 0.59 with an average of about 0.43. This agrees closely with the reference specific gravities used to estimate fuel loads. For hardwoods, the range is from 0.34 to 0.88 with an average of about 0.57.

A table of specific gravities was developed from analysis of the 37 major forest types described in the U.S. Department of Agriculture, Forest Service Handbook No. 445 on Silvicultural Systems (1973). The specific gravities of the greater than 3-inch

Figure 5.--Graphic determination of correction factor to adjust fuel loads for variations in specific gravity.



material was taken from the Wood Handbook (U.S. Forest Products Laboratory 1974) and an average specific gravity calculated using the major timber types listed for each forest type. Two major groups were apparent: (1) forest types of the Rocky Mountains and westward; and (2) forest types east of the Rockies. This second group can be divided into two subgroups: (2a) Northern and northeastern forest types; and (2b) southern and southeastern forest types. The average specific gravities determined for the size classes by group are shown in table 2.

Rather than do extensive adjustment in the field, it is recommended that specific changes be made for computer processing. For field use, the adjustments should be minimized so estimates can be made quickly and provide reasonable answers. Use of figures 1 and 2 without correction for specific gravity may introduce a 20 percent error. This should be acceptable for field uses other than fuel management, in which case estimates should be processed by computer for maximum accuracy.

Mean Diameter Per Size Class

Adjustments to mean diameter of the size classes less than 3 inches should be done for the computer processing rather than field use. However, if one uses equations (2) through (6) in the appendix A (page 12) on a hand calculator and wants to change the mean diameter, he would have to go back to equation (1). The new diameter per size class would be used to establish new coefficients for the species of interest (Brown 1974; Brown and Roussopoulos 1974) in equations (2), (3), and (4). This seems to be imposing more precision than the estimate merits, but is possible if the user desires.

SUMMARY

This publication is intended to adapt for field use procedures described in *Handbook For Inventorying Downed Woody Materials* (Brown 1974). Accuracy of fuel estimates can be improved by individual measurements and use of specific data for a timber type. Tearout graphs are included in appendix B. The tearouts should be covered with plastic to extend their useful life.

Table 2.--*Specific gravities of fuel size classes by geographic sections of continental United States*

Forest group	Size classes (inches)				
	0.25	0.25-1.0	1.0-3.0	3+ sound	3+ rotten
Rocky Mountains westward	0.48	0.48	0.40	0.40	0.30
East of Rocky Mountains-Northern and Northeast types	.60	.60	.50	.50	.30
Southern and Southeast types	.70	.70	.58	.58	.30

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APPENDIX A

How the Graphs Were Developed

The planar intersect method for estimating the quantity of fuel by size class is described elsewhere (Van Wagner 1968; Brown 1971; Brown and Roussopoulos 1974) and will not be discussed here. It is assumed the data-taking procedures are understood and it is desired to convert that data to estimates of fuel quantity. Other methods of estimating slash fuel loadings have been investigated or developed (Morris 1970; Muraro 1970; Roussopoulos and Johnson 1973; Beaufait and others 1974). Brown (1974) noted that some of these methods may be more efficient to use in particular cases and should be used where applicable. However, use of the simple field procedures given in Brown's Handbook and use of these graphic aids can provide a quick, objective field assessment of fuel quantity. The information in figures 1 and 2 was developed from an equation presented by Brown and Roussopoulos (1974), equation (2).

The basic equation used for the graphs of fuel loads is:

$$w = (11.64) \left(\frac{\Sigma d^2}{N\ell}\right) \; s \cdot \propto \cdot c, \text{ tons/acre} \qquad (1)$$

where

(11.64) = conversion of volume to tons per acre
Σd^2 = sum of squared diameters for interceptions of pieces greater than 3-inch diameter, in^2
or = nd^2 for interceptions of pieces less than 3-inch diameter, in^2
n = number of interceptions
d = diameter of piece intercepted or the quadratic mean diameter of the size class less than 3-inch diameter, inches
N = number of plots taken
ℓ = length of the sampling plane in each plot, ft
s = specific gravity of fuels
$\propto$ = correction factor for nonhorizontal angle of fuel elements
c = correction factor for slope.

Assumptions were made for each size class and specific equations established for estimating fuel load.

1. For the size classes less than 3-inch diameter, the composite mean quadratic diameters determined by Brown (1974) were used:

<0.25 inch, $d = 0.123$ inch (0.312 cm), $d^2 = 0.0151$ in^2
0.25 - 1.0 inch, $d = 0.538$ inch (1.37 cm), $d^2 = 0.289$ in^2
1.0 - 3.0 inches, $d = 1.661$ inches (4.22 cm), $d^2 = 2.76$ in^2.

These are assumed typical for all western conifers.

2. The specific gravities used were established by Brown (1974) for western conifers:

<0.25 inch, $s = 0.48$
$0.25 - 1.0$ inch, $s = 0.48$
$1.0 - 3.0$ inches, $s = 0.40$
Sound 3+ inches, $s = 0.40$
Rotten 3+ inches, $s = 0.30$.

3. Correction factors for the nonhorizontal angles of fuel particles were based upon the work of Brown (1974) and Brown and Roussopoulos (1974). Slash was found to have slightly higher factors than naturally fallen material. Ponderosa pine slash had the highest correction factors but for general use the following factors were used:

<3.0 inches, $\alpha = 1.13$
3+ inches, $\alpha = 1.0$.

The fuel particles greater than 3 inches in diameter are mostly bole material and large branchwood that, due to gravity, will tend to become positioned parallel to the ground.

4. No correction for slope was included, assuming that the sampling plane was on a nearly level surface. The correction factor then is 1.0. The error in load is less than +4 percent when the slope is 30 percent or less.

The equations used to develop the graphs expand from equation (1) to the following

<0.25 inch

$$w = 0.09533\ n/(N\ell) \text{ tons/acre} \tag{2}$$

0.25 to 1.0 inch

$$w = 1.825\ n/(N\ell) \text{ tons/acre} \tag{3}$$

1.0 to 3.0 inches

$$w = 14.52\ n/(N\ell) \text{ tons/acre} \tag{4}$$

Sound 3+ inches

$$w = 4.656\ \Sigma d^2/(N\ell) \text{ tons/acre} \tag{5}$$

Rotten 3+ inches

$$w = 3.492\ \Sigma d^2/(N\ell) \text{ tons/acre} \tag{6}$$

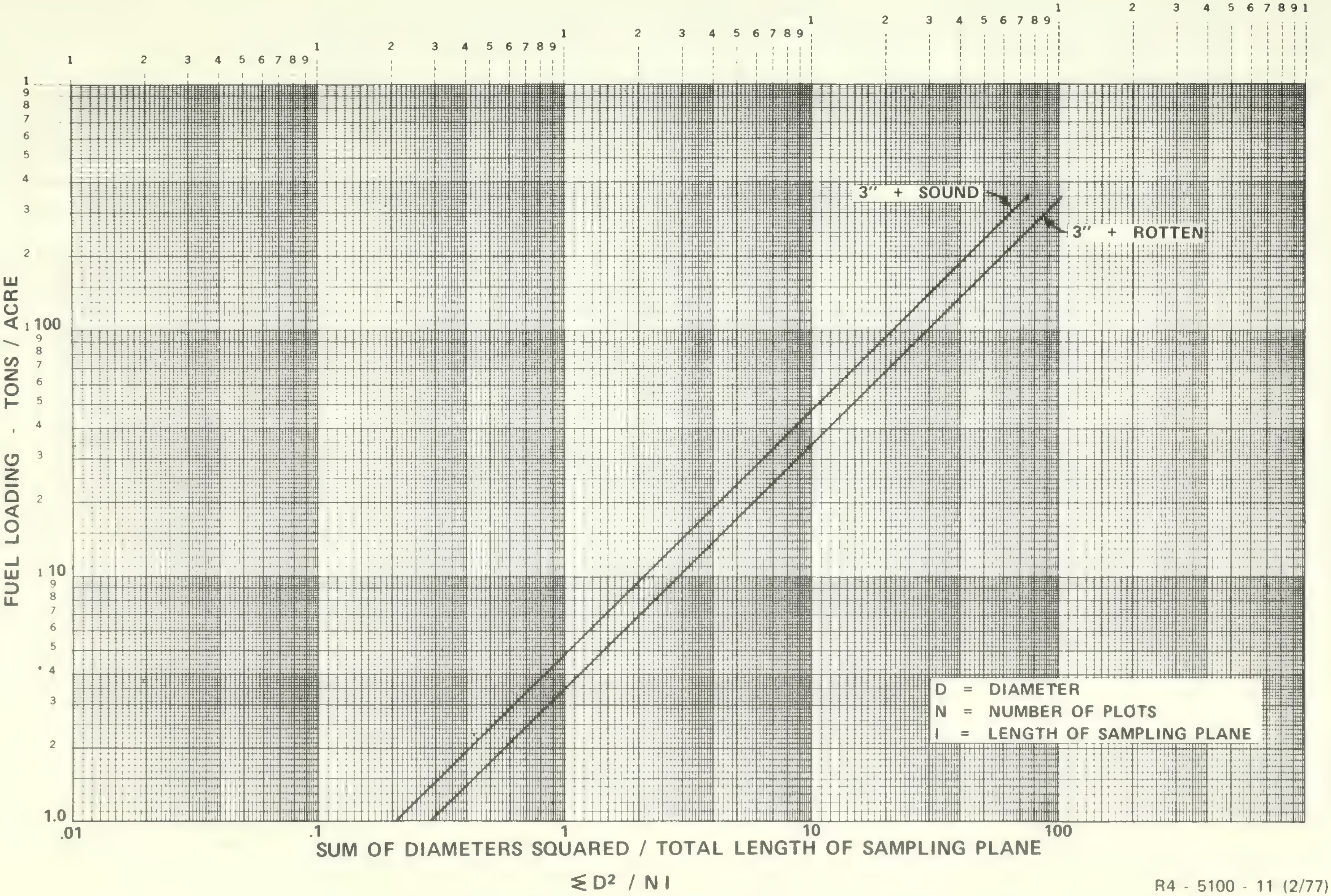
APPENDIX B

Tearouts for Computing Fuel Load, Corrections for Slope and Specific Gravity

Table 1.--*Sum of squared diameters for a given diameter and interceptions up to 10*

Diam-eter	Diam-eter^2	Σd^2 for (n) - number of pieces intercepted										
		1	2	3	4	5	6	7	8	9	10	
Inches	*In*^{2}											
3	9	9	18	27	36	45	54	63	72	81	90	
4	16	16	32	48	64	80	96	112	128	144	160	10 tons/acre
5	25	25	50	75	100	125	150	175	200	225	250	
6	36	36	72	108	144	180	216	252	288	324	360	
7	49	49	98	147	196	245	294	343	392	441	490	
8	64	64	128	192	256	320	384	448	512	576	640	50 tons/acre
9	81	81	162	243	324	405	486	567	648	729	810	
10	100	100	200	300	400	500	600	700	800	900	1,000	
11	121	121	242	363	484	605	726	847	968	1,089	1,210	
12	144	144	288	432	576	720	864	1,008	1,152	1,296	1,440	
13	169	169	338	507	676	845	1,014	1,183	1,352	1,521	1,690	150 tons/acre
14	196	196	392	588	784	980	1,176	1,372	1,568	1,764	1,960	
15	225	225	450	675	900	1,125	1,350	1,575	1,800	2,025	2,250	
16	256	256	512	768	1,024	1,280	1,536	1,792	2,048	2,304	2,560	
17	289	289	578	867	1,156	1,445	1,734	2,023	2,312	2,601	2,890	
18	324	324	648	972	1,296	1,620	1,944	2,268	2,592	2,916	3,240	
19	361	361	722	1,083	1,444	1,805	2,166	2,527	2,888	3,249		300 tons/acre
20	400	400	800	1,200	1,600	2,000	2,400	2,800	3,200			
22	484	484	968	1,452	1,936	2,420	2,904	3,388				
24	576	576	1,152	1,728	2,304	2,880	3,456					
26	676	676	1,352	2,028	2,704	3,380						
28	784	784	1,568	2,352	3,136							
30	900	900	1,800	2,700								
35	1,225	1,225	2,450									
40	1,600	1,600	3,200									
45	2,025	2,025										
50	2,500	2,500										
60	3,600	3,600										
70	4,900	4,900										
80	6,400	6,400										
90	8,100	8,100										

DEAD - DOWN FUEL LOADING FOR FUELS > 3 INCH DIAMETER
SOUND AND ROTTEN - FROM FUEL INVENTORY



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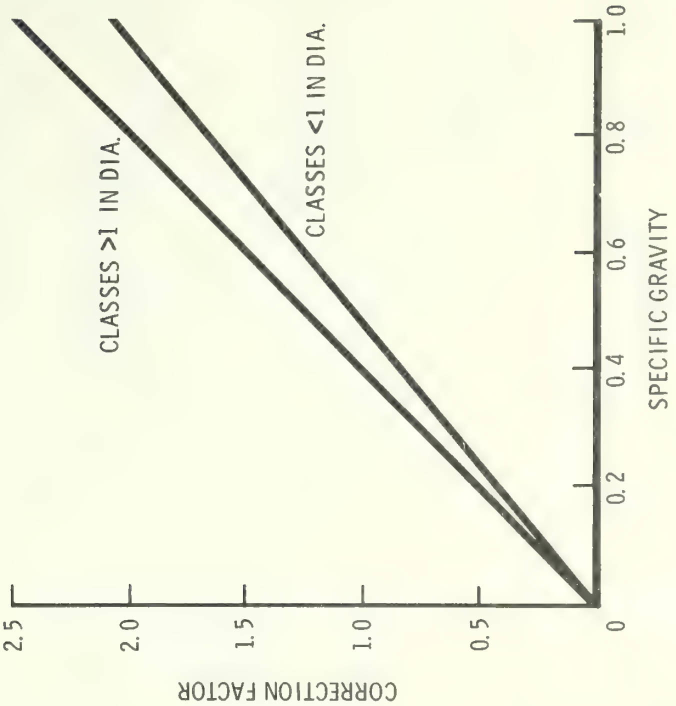

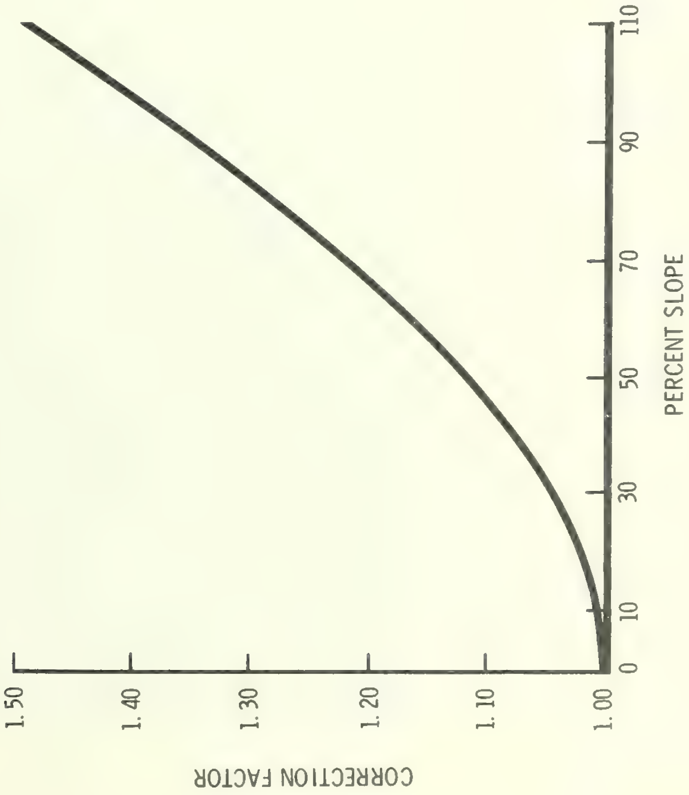

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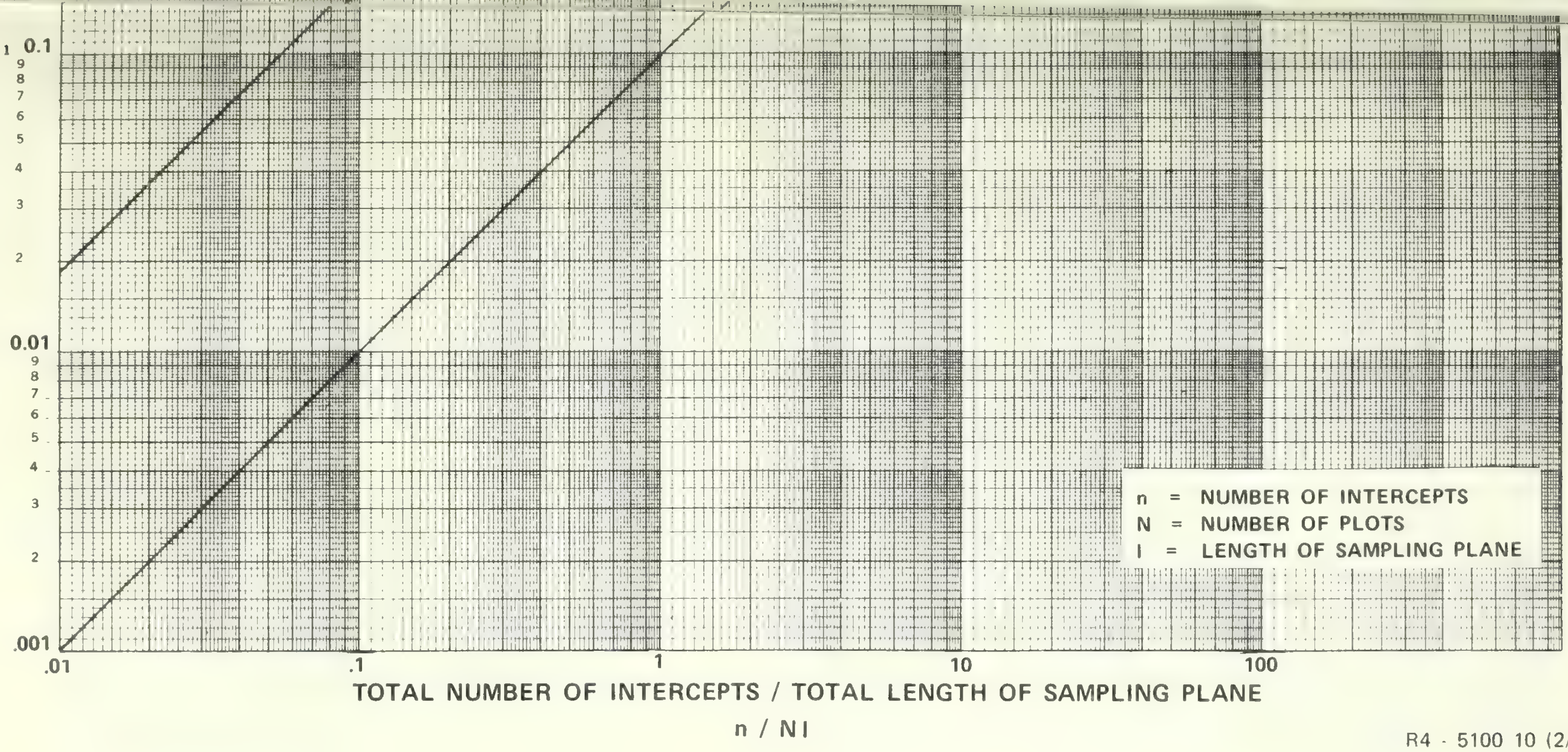

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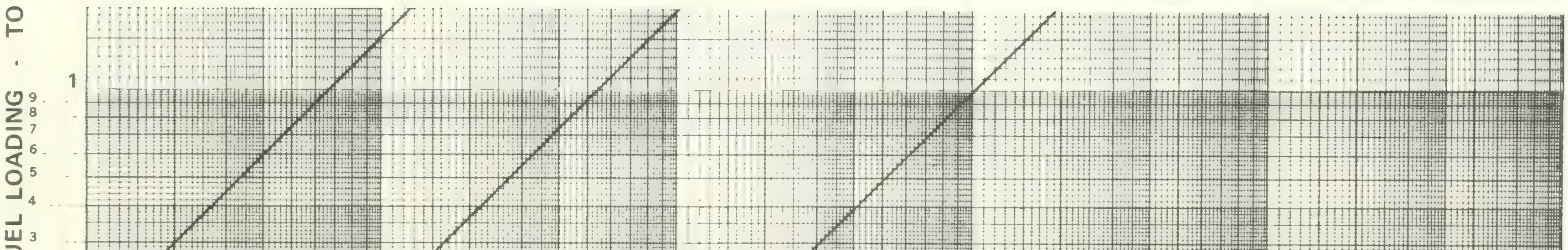

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Provides graphic aids to facilitate calculation of fuel loads from planar intersect sampling desired in "Handbook for Inventorying Downed Woody Material" (Brown 1974). Includes graphs for increasing accuracy by correcting slope and specific gravity.

KEYWORDS: fuel inventory, biomass, simulation, modeling.

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